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Preface

Occupational and Environmental Safety and Health is a compilation of the most recent work of some selected authors from 14 countries within the domain of occupational safety and health (OSH). The included works are focused on selected topics, including occupational safety, risk assessment, safety management, ergonomics, management systems, environmental ergonomics, physical environments, construction safety and human factors, among others.

This book represents the state of the art and it is mainly based on research carried out at universities and other research institutions, as well as some on-field interventions and case studies. Due to the broad scope, relevance and originality of the contributions, it is expected that this book contains useful and up-to-date information, and it presents fundamentally scientific research that is being carried out in the subject, as well as it contributes to the outreach of practical tools and approaches currently used by OSH practitioners in a global context. All the included contributions were selected based on their potential to show the newest research and approaches, giving visibility to emerging issues and presenting new solutions in the field of occupational safety and health.

The book is based on selected contributions presented at the 15th edition of the International Symposium on Occupational Safety and Hygiene, which was held on 15–16 April 2019, in Guimarães, Portugal. All the contributions included in this book were previously peer reviewed by, at least, 2 of the 131 members from 17 different countries of the International Scientific Committee/Reviewers of the 2019 edition. This event is organised annually by the Portuguese Society of Occupational Safety and Hygiene (SPOSHO).

The Editors would like to take this opportunity to thank their academic partners, namely, the School of Engineering of the University of Minho, the Faculty of Engineering of the University of Porto, the Faculty of Human Kinetics of the University of Lisbon, the Polytechnic University of Catalonia and the Technical University of Delft. The Editors also would like to thank the scientific sponsorship of several academic and professional institutions, the official support of the

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Part I
Occupational and Environmental Safety

Safety Management Plan for Equipment Used in Working at Heights

Sybelle M. S. L. Bastos, Bianca M. Vasconcelos, Suellem Attila Parisi, Tomi Zlatar and Béda Barkokébas Junior

Abstract The study aimed to present an occupational safety management plan for equipment used in working at heights to guide companies to comply with legislation, and, consequently, reduce the percentage of accidents at heights. First it was conducted a bibliografic review. Afterward, a field research was carried-out in a company leasing equipment for working at heights. A check-list was used to verify the compliance of the studied company with normative items on equipment and control measures. Finally, a quantitative and qualitative analyzes was carried-out, and developed a safety management plan for equipment used in working at heights. The results revealed that neither one sample was in accordance with all the considered items, evidencing that the companies have risks of accident. Finally, the management plan for working at heights and the usage of equipments has an important function of alerting, directing, increasing awareness and guiding companies to comply with the legislation, and can be incorporated into equipment leasing companies, as in companies which have these types of equipments used in working at heights.

Keywords Construction · Work at height · Equipment used in working at heights · Safety management plan

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1 Introduction

According to the Brazilian Statistical Yearbook of Social Security, in 2015, there were 41,012 work accidents in the civil construction sector in Brazil [1]. Among these accidents, according to the Brazilian Ministry of Labour and Employment [2], one of the main causes is due to events involving falls of workers from different heights. The [2] also points-out that the risks of falling from heights exist in various branches of activities and in various types of tasks. For this reason it was elaborated the Brazilian regulatory norm NR 35—"Working at Heights", managing the aspects of occupational safety and health for all the activities developed at heights and with risk of falls. Information on work accidents and incidents allows the improvement of occupational safety and health standards; as well as the conceptions and designs of machines, equipment and products; company management systems; technological development; working conditions; and systems reliability [3]. In addition, this knowledge promotes the reduction of ban or embargo of companies which have equipment used in working at heights. Therefore, this study aims to present an occupational safety management plan for equipments used in working at heights, in order to guide companies to comply with the legislation, and, consequently, reduce the number of accidents caused by falls from heights.

2 Context

The Occupational Safety and Health Agency [4] estimates that 65% of construction works involve scaffolds. The purpose of these elements is to support the work during the construction building process in places with heights and difficulties to access. The use of scaffolds extends to other sectors, such as shipyards, construction of billboards, stages and even during decorating [5].

Accidents with scaffolds in construction occur all around the world [6]. Faced with this reality, research is constantly carried out to minimize the risks arising from activities which use this equipment. Saurin and Guimarães [7] developed a study on the ergonomic risks of work positions with loads on suspended scaffolds. Other research has addressed inadequate ergonomic techniques during the disassembly of scaffolds [8]. Barkokebas et al. [9] pointed out the need for such equipment in construction, however, he warns on the possibility of a serious accident in the event of mechanical failure on its axis. The study conducted by [10], which examined 113 scaffolds in different parts of the United States, produced some suggestions, among which it was the recommended that construction companies should outsource the assembly of scaffolds to specialized companies, since accident rates tend to be lower and that the adequacy of the type of scaffolds should be checked prior to the development of the work.

Brazilian Standard NBR 6494, which deals with scaffold safety, divides the scaffold into suspended, mechanical (light and heavy), in balance and simply supported [11]. Light suspended scaffolds can be divided into manually suspended platforms, electrically suspended platforms, manually suspended gondolas, electrically suspended gondolas and manually suspended chairs (individual equipment). The type of equipment to be installed depends on the results of the building evaluation study, dimensioning the scaffold structures.

Besides the correct choice of the type of scaffolds to be used, it is of great importance that the company has a implemented the Health and Safety Management System (HSMS) so that the equipment is properly used, without presenting risks to the workers. The HSMS consist of a general guidelines model, which points to the need of national guidelines with the objective of improving working environments, but it does not replace the legal structure of the norms, since its implementation has as minimum requirement the compliance with national legislation [12]. The correct implementation of a management system requires changes within the organization, both in its political scope and principally in its cultural scope, since people are responsible for the success of the results obtained.

The management plan allows the anticipation of risk identification and application of protective individual and collective control measures, thus generating a reduction of accidents at work, by giving guarantee to the physical integrity and health of the worker on his working place.

3 Methodology

For the present study, all types of light suspended scaffolds were considered. The research was structured in two phases. In the first, a field study was carried out in a company that leases machinery and equipment in the Northeast region of Brazil, considering 20 contracts in works located in the Metropolitan Region of Recife. In the second stage, it was developed a safety management plan for equipment used in working at heights. The plan aimed to serve as a tool for facilitating and directing companies to comply with the legislation.

Among the 20 collected contracts, 14 considered the manually suspended platform, three considered the electrically suspended platform, one the manually suspended gondola and four the suspended chair. There were no electrically suspended gondolas, but this didn't generate any loss, since this type of equipment is similar to the electrically suspended platform. Among the contracting companies, there were nine construction companies, nine maintenance companies and two industries. Regarding the type of work, the contracts involved 11 residential works, five commercial works and four industrial works. The study covered the phases of execution, finishing, cleaning and maintenance of facades.

For the field study, which was the first phase of this study, a check-list was structured regarding equipment used in working at height activities. The check-list was designed to identify whether workers were familiar with the risks involved during their operations, and to verify, according to current legislation, which measures of control were adopted by companies. In order to understand safety at work as a combination of technical, administrative, educational and medical measures, the questionnaire was organized in this four categories, as illustrated in Tables 1 and 2.

With the data collection and analysis, results were generated to evidence on the reality present in working at height activities. In the end, safety improvements were proposed to eliminate the identified risks in order to guarantee the worker's physical integrity and health, the company and its image before society.

In the second phase of the research, the safety management plan for equipment used in working at heights was elaborated, based on the results of the previous phase. This plan contemplates the norms related to the subject, with the flow-chart and detailing of all working at height activities by using previously mentioned equipment, as well as three inspection check-lists (initial inspection of the work to be performed, daily inspection and audit inspection).

Table 1 Analysed educational and administrative control measures

Measure	Question	Yes	No
Educational	Is the operation of scaffolding carried out by a capacitated or qualified professional?	15	05
	Is the installation of scaffolds carried out by a qualified professional?	15	05
	Is the maintenance of scaffolds carried out by a qualified professional?	19	01
	Were workers capacitated/trained for working at heights?	05	15
	In the assembly and disassembly, the employee has a badge of identification and qualification, including the last occupational examination and training?	00	20
Administrative	Check-list of daily inspection completed?	11	09
	Operational procedure of the service to be executed?	17	03
	Technical Equipment Manual?	20	00
	Issuance of the daily work permit?	10	10
	The dimensioning of scaffolds accompanies calculation memory, project and Technical Responsibility Note?	19	01
	Do the fixation and support systems have a respective Technical Responsibility Note project?	18	02
	Were the scaffolds assembled in accordance with the respective Technical Responsibility Note project?	18	02
	Equipment release recorded in the workbook?	08	12
	Periodic preventive maintenance/corrections recorded in the workbook?	07	13

Table 2 Analysed technical and medical control measures

Measure	Question	Yes	No	NA
Technical	Is the work area signalized and isolated?	15	05	00
	Does the facade have a protective net to protect from falling materials?	08	12	00
	Does the main building have a main platform?	14	06	00
	Has the company provided the necessary personal protective equipment?	20	00	00
	Do electrical equipments meet the requirements of the Brazilian regulatory norm NR 10?	03	00	17
	Were there permanent accesses to the equipment?	15	05	00
	Does the suspended chair contain, in its structure, the corporate name of the manufacturer and the national registry of legal entity?	00	02	18
	Was the suspended chair improvised?	00	02	18
	Does the panel of scaffolds contain the identification, lot and year of the manufacturer?	00	18	02
	Does the fixation or support system meet the requirements of the Brazilian regulatory norm NR 18?	16	04	00
Medical	Does the company have Medical Occupational Health Control Program?	16	04	00
	Does the Occupational Health Certificate contain the certificate of ability for working at heights?	12	08	00

NA—Not applicable

4 Findings, Analysis and Discussion

In the first step, that is, in the field study, the check-list was applied in order to evaluate among the responsible individuals on knowledge related to risks for working at height during construction working activities. Of the 20 studied companies, all were aware of the risk of falling from different levels of height, but no company considered the risk of falling from the same level and tipping/disruption of the fixation structure. From the interviewed, 17 perceived the possibility of accidents due to falling of material. Only three agreed with the risks related to winds and rains and to the breaking of the steel cable and rope. Only two companies were aware of risks related to electric shocks, chemicals, physical and biological agents.

In addition to verifying the level of risk knowledge, the companies did not consider planning before the service was performed. In addition to evidencing ignorance of the standard, this fact contradicts the requirement of the Preliminary Risk Analysis, which is in accordance with the Brazilian regulatory norm NR 35. In the Preliminary Risk Analysis, the company should identify potential risks and choose the appropriate control measures to eliminate or neutralize the existing risks.

In the field study, the application of the check-list verified the compliance with the Brazilian legislation, which for working at heights search for largest disabilities in relation to control measures in the educational and administrative (Table 1), and technical and medical fields (Table 2).

According to Tables 1 and 2, there were non-conformities in 46, 29, 37 and 30%, respectively, for the analyzed educational, administrative, technical and medical control measures. That is, in total, 35.5% of measures were in disagreement with the legislation. It is clear that the educational measure was the most infringed by companies.

For the educational control measures, it was evidenced that the operators and professionals responsible for the installation of the equipment had experience in the operation and installation of the equipment, but the training for which were registered was not in the appropriate working activity. The training for working at heights was performed in only 25% of analyzed companies. In the assembling and disassembling service, there were no operators who used the appropriate identification and qualification badge.

For the administrative control measures, it was evidenced that 55% of companies registered their daily inspections through recordings of the inspected items in the check-list. However, although companies conducted their daily inspections, the activity was conducted even when the work was not according to the procedures specified by the check-lists. In some companies it was observed that, some operators conducted verification of the equipment, but they didn't fulfil the check-list.

Among the 20 evaluated companies, 50% issued work permits for the beginning of service between industries and construction companies. Some companies reported being aware of the need to issue work permits, but it was issued only for occasional works, or periodically, and in the minimum interval of three days.

Two companies had the Technical Responsibility Note for fixing the equipment, but the lifeline equipment was not installed in independent points, which was considered as an irregularity. In two maintenance companies, there was no documentation for the assembly of scaffolds, and in one of them, the assembly was still not in accordance with the standard. It was found that only 40% of the companies evidenced the equipment in the workbook and 35% registered maintenance.

For the technical control measures, it was verified that 75% of the analyzed companies had implemented signalization and protection against falls in affected areas. Only 40% of the works had facades with the protection screen, which is collective protection equipment. In 70% of construction works, the main building had its platform. In all the works, there were information of corporate name and the national registry of legal entity in the chairs, complete compliance in the supply of personal protective equipment and adequate electrical equipment. In the case of permanent accesses, the situation for the industries was considered to be critical, as works were carried out in corn silos and even fuel tanks, structures which have no access, having the operator to go up and down to access or leave the equipment.

For the medical control measures, three construction-maintenance companies did not have a Medical Occupational Health Control Program, and one more had this Program out of date. It was found that 60% of evaluated companies used records of ability for working at heights, specified by the Occupational Health Certificate. In some companies it was evidenced that in the registry was only recorded the aptitude of the professional performing the service, but not as well for their assistants, which were exposed to same risks.

A critical point in the application of check-lists was identified to be the failure to carry out the risk analysis before the beginning of the activity, so that the appropriate actions would be taken. In addition, the data showed that only falls from different height levels were considered as risk, which was considered by 100% analyzed companies. From this, it was concluded that there is a necessity to make a survey on all risks for working at height activities, and to associate them to corresponding control measures. Through the surveyed works, seven types of risks were grouped: different falling height level; same falling height level; rupture and tipping of the fixation structure; environmental (chemical, physical and biological) agents; breaking of steel cable and rope; influence of strong winds, rain and electric shocks.

Proposition for improvements

The study evidenced the need for the elaboration and implementation of a management plan to be applied by customers who use equipment for working at height. The implementation of this plan objective to: analyze through anticipation of risks and with evaluations; implement educational, administrative, technical and medical control measures; comply with legislation when planning and in the execution of installations; and periodically audit the activities, equipment and labour involved.

The safety management plan for equipment used in working at heights, is composed of a flow-chart (covering the systematic of all performed activities), and three check-lists (initial, daily and the check-list for audit inspections). The Brazilian standard NBR 6494 (Safety on scaffolding) and the regulatory standards NR 6 (Personal protective equipment), NR 12 (Safety in machinery and equipment), NR 18 (Conditions and working environment in the construction industry), NR 35 (Safety and health at work in height) were used for the preparation of these checklists.

The initial inspection check-list verifies that all steps have been planned to ensure that all observed risks are eliminated or minimized with the implementation of control measures. The daily inspection check-list includes all items necessary for companies to identify non-conformities and take immediate action to eliminate or minimize risks. This check-list should be completed for all installed equipment, on daily basis to be checked under the supervision of a legally authorized professional with its release. The audit check-list was designed to verify the educational, administrative, technical and medical control measures for working at heights activities. Audits should be conducted monthly in order to verify compliance and non-conformities.

Briefly, the Working at Heights Management Plan for studied Equipments, fulfils the following items: 1. Careful analysis of all risks involved in the activity; 2. Hiring qualified professionals for working at heights; 3. Hiring the adequate equipment to perform the service; 4. Working at height training lasting 8 h; 5. Referral of the professionals for the necessary exams according to the Medical Occupational Health Control Program; 6. Registration of Occupational Health

Certificate in the term “able to work at height”; 7. Implementation of the necessary collective measures to carry out the work; 8. Project of equipment installation with specific Technical Responsibility Note; 9. Purchase, supply and registered training for correct use of all personal protective equipment; 10. Registered training of implementation procedures for specific services; 11. Release of work permits; 12. Medical control according to the type of service; 13. Installation of collective protection equipment; 14. Installation and assembly of equipment according to the execution project; 15. Release of equipment with the issuance of Technical Responsibility Note and registration in the workbook; 16. Employee training for executing the equipment; 17. Issuance of the identification badge with the registration of the last Occupational Health Certificate; 18. Maintenance of equipment by a qualified professional with supervision from a legally qualified professional; 19. Completion of the initial inspection check-list; 20. Completion of daily inspection check-list; 21. Isolation of the area for working at heights; 22. Service execution as instructed on trainings and using required personal protective equipment; 23. Periodic audit verifications.

5 Conclusions

The Working at Height Management Plan consists of a flow-chart and three check-lists. The flow-chart makes possible the clear and sequential visualization of the tasks performed in the working at heights, as well as, it supports the application of the check-lists. Check-lists for initial, daily, and audit checks should be applied at the time relevant to each. The implementation of the plan in companies has the potential to have a positive impact, where the rental company that has co-responsibility as contractor is safeguarding and taking all necessary actions in the lease agreement, avoiding accidents. In addition, this generates a satisfactory loyalty between the one contracting and one being contracted, thus supplying the interests of the companies.

Many companies are aware of the need to implement educational, administrative, technical and medical control measures for performing work at height. However, due to the presented reasons, these measures are not applied. One of these reasons is the lack of planning, which makes the hiring or purchase of the equipment done indiscriminately. This fact causes losses, since, it is essential to apply appropriate measures before starting the work at height-activities. The observations on items defined in the proposed plan leads the company to comply to the legislation, generating a decrease in the possibility of an accident occurrence. Finally, the developed safety management plan for equipment used in working at heights is a useful and practical tool of interest to companies owning and/or leasing equipment for working at heights.

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Risk Assessment in the Open Pit Mining Industry—A Short Review

Jacqueline Castelo Branco, Rania Rebbah, J. Duarte and João S. Baptista

Abstract The extractive industry is simultaneously one of the human civilisation pillars for the resources it provides, but also one of those with the highest accident index. The quarries exploitation, amongst all extractive industry activities, being considered a high-risk occupation in which, due to the development of their respective professional activities, the workers are exposed to risks that may impact on their health as well as in their physical integrity. This work aimed to identify risk assessment methods specifically used in the open pit mining industry. The research of information was based on the PRISMA methodology, where 12 databases with the appropriate keywords were searched. A total of 38,594 articles were obtained, and 42 were selected after the sorting process. It was verified that the risk assessment methods specifically addressed to the extractive industry were fundamentally destined for environmental and geological risks; for occupational risks, general evaluation methods were used. This scenario leaves open the necessity of developing methods specifically aimed at assessing the accident risk in the open pit mining industry.

Keywords Risk assessment · Open pit mining · Occupational safety

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1 Introduction

The need for mineral resources is of crucial importance whether in the world economy or people's daily lives, since the vast majority of consumer goods and industrial activity depend, in some way, on this industry [1]. However, the mining activity has its own characteristics, distinguishing it from all others [2]: it has an inescapable rigidity as far as location is concerned, it explores nonrenewable resources and, in most cases, involves the modification of the local landscape [3]. Along with its high economic potential, it is often associated with substantial costs externalisation, whether at the environmental and occupational levels [4, 5]. In the Open Pit Mining Industry [OPMI], the environmental and landscape impacts are unavoidable, and it is a sector with the highest occupational accident index [6]. Therefore, it is fundamental to overcome these constraints in order to guarantee their own sustainability [7].

From the occupational point of view, raises the question of what are the applicable methodologies for risk assessment and, whether there is already some duly validated to deal with the problem of high accident index in the sector. The use of matrix-based or control-band methods is widely disseminated and affirmed among safety technicians for their simplicity and ease of implementation. However, these methodologies have a basic problem, which is the lack of reproducibility and reliability.

However, risk assessment methodologies directed to the extractive industry have their primary focus on environmental risks, on the water contamination, soil and geological risks, where they are quite efficient [8–11].

Most of the existing methodologies for occupational risks are based on information subjected to uncertainty, imprecision and ambiguity, from which the results are sometimes different when applied to the same case [12–15]. Added to these factors the singularity and particularity of each exploration on geological and operational terms [16–18]. In this context, the main objective of this work was to survey the risk assessment methodologies mostly used in OPMI.

2 Review Methodology

In order to find an answer to the proposed objective, the present investigation work began with a bibliographical review according to the methodology presented in the PRISMA Statement [19]. The bibliographical search was carried out in Web of Knowledge databases [Current Contents, Inspec e Web of Science], Scopus and Academic Search Complete. Elsevier [Science Direct], IEE Xplore, Emerald, Taylor and Francis, Pubmed, Medline, SpringerLink, SAGE Journals Online and Geological Society of America [GSA] were also consulted.

The used keywords considered the following combinations: "Risk assessment" AND "mining" AND "occupational"; "Risk assessment" AND "extractive industry" AND "occupational"; "Risk Assessment" AND "Open Cast" AND "Occupational"; "Risk Assessment" AND "Open Pit Mine" AND "Occupational"; "Risk Assessment" AND "Quarry" AND "Occupational"; "Risk Assessment" AND "Quarries" AND "Occupational"; "Risk Assessment" AND "Mines" AND "Occupational; "Risk Assessment" AND "Mine"AND "Occupational"; "Hazard" AND "Mining" AND "Occupational".

Articles in the publication phase, book chapters, and conference papers were considered between January 2005 and September de 2018.

3 Bibliographical Search Results

Initially, 38,594 articles were obtained. Of these, 38,273 were excluded after applying the inclusion and exclusion criteria: 17,068 because they were not within the period considered, 2337 were not written in the English language, 1349 were duplicates, 6512 per document type.

After reading the titles and summaries, 11,007 were excluded because they were not related to the topic, were not methodologically compatible with the present work, or were within the underground mining industry.

After this process, 321 articles were considered eligible for a full reading, of which 279 were excluded after analysing their suitability to respond to this work objective. At the end of this process, 42 articles were included in the present short review to analyse the full text and verify the occupational risks inherent to the open pit mining industry and the risk assessment existing methodologies and applicable to the context of the present study.

4 Results for Risks Evaluation in OPMI

The results of the present bibliographic research point in the same sense of the studies carried out previously in 1999 and 2010 [20, 21], i.e., there was no significant evolution since then in risk assessment and management of accidents methods at OPMI.

Most of the existing risk assessment methodologies present a specific objective directed to an area and do not link the integration between the occupational variables and the productive process, nor do they validate any analytical tool.

In this context, several authors suggest the integration with other quantitative methodologies. As an example, the Monte Carlo Method is highlighted [8], the geostatistical simulation, numerical modelling and the fuzzy set theory [11]. This last one intends to model the uncertainty associated with risk assessments, allowing the inclusion of the human factor. There are records of its use in the area of ergonomics and evaluation of occupational hazards [9, 18]. The fault tree method is also used for the analysis of accidents, and the study of their possible causes [22].

Even though there are a wide variety of methodologies for identification and risk assessment, it does not exist one that frames the production process in the OPMI. Besides, most of the existing methodologies are based on information that is subject to uncertainty, imprecision and ambiguity, where results are sometimes different when comparing methodologies applied to a particular case [12–15]. Additionally, the singularities and particularities of each exploration on geological and operational terms have also to be considered [15–17].

4.1 Quantitative Methodologies

Quantitative methodologies account for about 65.3% of all identified risk assessment methodologies [23]. The fault tree method and tree survey analysis, as well as their multiple conjugations, are some examples [22, 24] They consist of the quantification of the different risk elements, namely, the probability and severity of the consequences. This quantification is made using mathematical models in which the variable "probability" can be determined by making use of relatively sophisticated calculation techniques [14, 20, 25]. However, the complexity and slowness of its implementation, as well as the quantity and quality of data required, are an impeding factor in OPMI, since each exploration is a particular case, without the practical possibility of creating an effective and global history of accidents [14, 24]. Several authors, therefore, agree with the limitations that the methods of the probabilistic base present, namely a referred lack of data, measurement errors or subjective interpretation of them [18]. As a disadvantage of this type of methodology, the slowness and complexity of calculations are highlighted, in addition to the need for structured databases in order to build a history.

4.2 Semi-quantitative Methodologies

This type of approach represents only 6.7% of all identified risk assessment methodologies [23].

These methodologies proceed to quantify the verisimilitude and severity using matrices and descriptors [16]. Falling within this typology, for example, the Somerville Simple Matrix Method, the Simple Matrix Method [3 × 3] [26, 27] and the CRAM Simple Matrix Method [28]. They are still included in these typologies, among others, the methods of William Fine [29, 30], the Simplified Accident Risk Assessment System [NTP 330] developed by INSHT—El Instituto Nacional de Seguridad e Higiene en el Trabajo [31, 32] and the Metodologia Integrada de Avaliação de Riscos Ambientais e Ocupacionais [MIAR] [12, 14, 20, 33].

The application of these methods is straightforward and does not require an exact identification of consequences [20, 34–39].

Its ambiguity is nevertheless recognised, as the result is dependent on the technician experience [18, 20, 23, 40].

In most of the comparisons made between different methodologies, the results show the existence of statistically significant differences between the different levels of risk obtained [14]. In the few comparative studies that are known, the need to deepen scientific knowledge is reinforced, in order to guarantee the reliability of the risk assessments carried out [12, 14].

4.3 Qualitative Methodologies

They account for about 27.68% of all identified risk assessment methodologies [23]. These can be defined as a qualitative and systematic review of the workplace, where it analyses each situation, intending to identify what are the situations that could put workers at risk [14]. They have the advantage of simplicity, however, have the disadvantage of being highly subjective and dependent on knowledge of the evaluation teams [20, 40].

They are used as the initial screening process for the identification of hazards and risks, or when quantification is not justified [14].

Within these approaches, Checklists and Task Analysis use as the central tool the exhaustive survey of the hazards related to a given activity and the conditions of implementing safety practices associated with each one [14, 20, 30].

The risk survey shall be exhaustive, detailed and systematic, comprising at least the following aspects:

- Material working conditions—equipment, substances or materials;
- Environment and workplace—work environment;
- Work organisation of and prevention management: type of the task and organisation, training, information, and communication and management failures;
- Factors of individual nature.

These methodologies are even more effective with a higher quality of the generated list and depend on the sensitivity of the evaluator [20, 23, 30]. There are numerous checklists available and adaptable to the sector of activity to be analysed [41–43].

The Hazard and Operability Study [HAZOP] can be used either for the identification of occupational aspects, as well as environmental and related to the production process [44]. This methodology is useful in the project implementation phase since it can act on design level [23, 34, 41, 44–46]. As a disadvantage, the slowness of the evaluation process is highlighted [20, 45].

Failure Mode Effect Analysis [FMEA] is based on the study in the process steps, and the identification of potential failures and that could occur in each component [47]. For each of these situations, causes and effects are identified. The capability of detecting this failure and the probability of occurrence are evaluated so to determine the risk level of each failure mode [20, 48]. As for disadvantages in its application, the fact of requiring a large amount of data can be stressed. It also requires that all processes should be in operation [49].

The What-if methodology is used in process risk review and is recommended as the initial basis for risk analysis, as it aims to determine possible scenarios that result in failures in operation of specific equipment, in the work performed by the operator or in the used materials [12, 33]. However, experienced evaluators are required, which in its turn leads to results depending on the evaluation team [12, 33, 49].

The Qualitative Occupational Risk Assessment Model [QRAM] is constructed under four dimensions: Climate Security [SC], Severity Factor [S], Factors of Possibility [PF] and Safety Barriers [SB], has been specially designed for use in the construction industry, in particular for determining the risk in falling situations, burial, electric contact and drowning. This type of methodologies carries out risk analysis taking into account human factors. Within these methodologies can be highlighted the tasks analysis and human errors analysis [20, 21, 23].

5 Conclusions

Having surveyed the existing risk assessment methods applicable to OPMI, it was found that, despite their large number, the methods are either dependent on the existence of data that are difficult to obtain [in many situations impossible to obtain] or in general quantitative methods; or are of uncertain reproducibility. Since the results depend on the evaluator and his experience, as is the case with semi-quantitative methods; or to have some reliability, require experienced teams and time-consuming and costly processes as in the qualitative methods identified.

It has been found that, in reality, there is no method to respond quickly and at low cost while being reproducible and reliable. This detected gap opens up a field of research that is worth exploring.

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Occupational Accidents in Brazil and Portugal: A Comparative Study

Daniele Costa, Victor Esteves, Bruna Faustino and Claudia Morgado

Abstract Brazil and Portugal are countries with strong cultural and social ties. Recent agreements have facilitated the transit and exchange of professionals and companies between the two countries. In this context, comprehension of the main differences between the legal framework regarding occupational health and safety (OHS) of each country is an important challenge for companies and individuals. This article explores the existing differences of OHS management in both countries by performing a literature review of the OHS policy framework of each country, from which a comparison of their core requirements and compensatory measures is carried out. Additionally, an evaluation of the statistics of work-related accidents and occupational diseases is presented. The study shows that there are several differences on the OHS frameworks and both countries face the challenge of improving their occupational diseases databases.

Keywords Occupational health and safety · Statistics · Brazil · Portugal

1 Introduction

Relations between Brazil and Portugal go far beyond the historical dimension. This is reflected in several cooperation agreements, such as the Agreement on Facilitating the Circulation of People, the Agreement on Reciprocal Hiring of

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Nationals and the Cooperation Agreement for the Prevention and Suppression of the Illicit Traffic of Migrants, all dating from 2003 [1]. In 2015, a reciprocity agreement was established between regulatory and licensing bodies for the engineering profession in both countries, namely the Brazilian Federal Engineering and Agronomy Council (or CONFEA) and the Portuguese Order of Engineers (or OEP) [2]. According to this agreement, the qualification of Portuguese and Brazilian engineers can be recognized in both countries, facilitating the exchange of professionals.

Expertise about occupational health and safety (OHS) is particularly relevant in this context since there is also a guarantee of social security rights of workers of both countries and their legal dependents [3] that calls for a mutual understanding of work practices and applicable legislation. However, the legal structure for regulation and response with respect to OHS differ significantly between the countries and studies presenting a detailed comparison of their main aspects are scarce. Therefore, this study explores the relationship between the Brazilian and Portuguese OHS legal framework, to discuss the occurrence of work-related accidents and diseases and to present the existing compensation system for work-related accidents and occupational diseases in these countries.

2 Methodology

This study presents a literature review of the current OHS policy framework of each country and then a comparative study of the legislation and statistics on work-related accidents and occupational diseases. Statistical data are presented and discussed to explain the differences. The Brazilian databases used were MPS [4] and IBGE [5], while Portuguese databases were Pordata [6] and GEP/MTSSS [7].

A period of ten years (2006–2015) was adopted for the comparison of accidents, due to the limitation of the databases. The accident rates are given per 100,000 workers both for total and fatal accidents. A classification by economic sector was also performed considering 2014 and 2015 due to the differences among databases.

3 Results and Discussion

3.1 Brazil

The Brazilian Labor Code (the Consolidation of Labor Laws [8]), was enacted to govern labor relations in Brazil in a context of increasing industrialization and migration of workers from the countryside to the city [9]. OHS regulations were subsequently restructured by Law nº 6.514/1977 [10]. The Ministry of Labor has the responsibility to issue specific regulations, standards, and rules to complement this legislation. The Brazilian OHS standards, also known as Normas Regulamentadoras or simply NR were regulated in Ordinance nº 3.214/1978 [11]. These standards apply to all work facilities, private or state-owned, and cover a variety of topics.

Standards for OHS oversight within companies are defined by NR 4 [12]. Units called 'Specialized Occupational Health and Safety Engineering Services' (*Serviços Especializados em Engenharia de Segurança e em Medicina do Trabalho*—SESMT) for companies are set according to the number of employees and risk level of the company's main activity. The SESMT includes technicians, an engineer, assistant nurse, nurse and doctor with specialization in occupational health and safety. Companies are also required, if exceeding a certain threshold of a number of employees and risk level, to establish an Internal Accident Prevention Committee (*Comissão Interna de Prevenção de Acidentes*—CIPA) [13].

In addition, programs for medical control of occupational health (PCMSO) for every worker as well as a program for the prevention of workplace hazards (PPRA) are mandatory [14, 15]. The reorganization of the health sector in 1988 into the Unified Health System (*Sistema Único de Saúde*, SUS), under the Ministry of Health, has shifted some responsibilities from the Ministry of Labor to the SUS [16].

The PCMSO includes the schedule of medical examinations according to risks related to the tasks performed and the age group [14]. The following categories of examination exist: hiring, periodic, return to work (after sick or accident leave), functional change and dismissal. Exams required are defined according to the exposure to occupational risks reported in the scope of the PPRA [14, 15].

In Brazil, an accident is defined as an event that occurs because of work or while performing work duties, causing personal injury or functional disorder that causes death, loss or reduction in the ability to work, either permanently or temporarily [17]. The definition of accidents includes (i) accidents that occur due to work activities, (ii) accidents while commuting to and from work, (iii) occupational disorders, and (iv) work-related illnesses.

Accidents must be reported by the employer to the National Social Security Institute (INSS) through an instrument called Communication of Occupational Accident (CAT). Accidents have to be notified until the first working day following the occurrence or immediately (in the event of death), under penalty of a variable fine [18]. Accident statistics typically are kept according to the Brazilian standards [19].

The compensation system is regulated by the Civil Code [20] and coexists with a wide array of laws and regulations that specify benefits. Compensation for work accidents was integrated into the social welfare system in 1967 [21], setting the legal basis for compensation and detailing which situations apply. Today, Law nº 8.213/1991 [17] and Decree nº 3.048/1999 [18] form the main legal framework for the compensation of work-related accidents and occupational diseases, although these are also covered by other legal instruments [22].

These rules consider different social benefits, such as retirement benefits, maternity leave, among others. The available benefits for work-related accidents or occupational diseases, are: (i) accident aid, (ii) sickness/disease aid, (iii) special retirement (for workers that were exposed to specific chemical, physical and/or biological hazards), (iv) invalidity pension, and (v) death pension to dependents. Benefits are granted based on the "contribution salary" of the worker. The payment of those benefits is made through the Worker Accident Insurance (*Seguro Acidente do Trabalhador*, or (SAT) [17].

3.2 Portugal

As a member state, Portugal complies with European Union legislation. The European Framework Directive on Safety and Health at Work [23] was adopted in 1989 and gives freedom to member states to rule on the organization of OHS services and professional training at the national level. In this Directive, several aspects are defined, including obligations of employees and employers.

The Labor Code [24, 25] establishes general principles concerning OHS in Articles 281–284. However, the main regulation for OHS in Portugal is Law nº 3/2014 [26], which includes the figure of workers' representative for OHS. Law nº 102/2009 [27] also includes the possibility of the creation of workers' committees for OHS issues. As for the government entities, two stand out: The National Council for Health and Safety at Work (*Conselho Nacional de Higiene e Segurança do Trabalho*—CNHST) and the Authority for Working Conditions (*Autoridade para as Condições do Trabalho*).

There are two main types of OHS services: internal and external (or common), which as the names suggest, depends on whether it is mandatory for a certain company to have an internal service. External OHS services can only be rendered by accredited companies and only when internal services are not mandatory.

Regarding occupational health, Law nº 102/2009 [27] and Law nº 3/2014 [26] define requirements for the realization of physical exams. There are three exam types: hiring, periodic and occasional. The exams are performed considering the risk exposure defined by the occupational health physician [27].

In Portugal, a work accident is defined as any unforeseen event that occurs in the workplace during working hours that directly or indirectly produces bodily injury, functional disturbance or illness that results in a reduction of work capacity or death. This classification includes: (i) commuting accidents, (ii) occupational injuries and illnesses; and (iii) incapacity to work [28].

Severe or fatal accidents must be reported within 24 h [26]. For the statistical treatment of accidents, there is no specific Portuguese standard. However, it is recommended to use the method proposed at the 16th International Conference of Labour Statisticians [28].

In Portugal, the compensation system is regulated by articles 283 and 284 of the Labor Code [24, 25] and details the worker's and family members' rights to compensation for either workplace accidents or work-related diseases as well as who has the responsibility for monetary compensation. For work accidents, this responsibility lies with private insurance companies, which are accredited and supervised by the Insurance and Pension Fund Supervision Authority (*Autoridade de Supervisão de Seguros e Fundos de Pensões*, or ASF). The ASF also manages the Work Accident Fund (*Fundo de Acidentes de Trabalho*) for the cases where insurance companies are not capable of paying, and for work-related diseases, this responsibility lies with the Social Security System (under the Ministry of Labor, Solidarity and Social Security).

Law nº 98/2009 [29] regulates not only the system for compensation for work accidents and occupational diseases but also the rehabilitation and reintegration of workers afterward. Incapacities following a work-related accident or disease are classified as temporary or permanent in Law nº 98/2009 [29]. The first is further divided into (i) partial and (ii) absolute. In the second group, it is further divided into (i) partial, (ii) absolute for the execution of the habitual work, and (iii) absolute for the execution of any work.

3.3 Comparative Analysis

The Brazilian and Portuguese legal frameworks for OHS regulation are complex and their structure differs significantly. Portuguese technical legislation on different OHS themes is scattered over a set of directives and laws, while in Brazil the main requirements are grouped in the NR. However, the Portuguese compensation

Table 1 Comparative study of the compensation system for work-related accidents and occupational diseases in Brazil and Portugal

Aspect	Brazil	Portugal
Main legal framework[a]	Law nº 8.213/1991 [17] Decree nº 3.048/1999 [18]	Law nº 98/2009 [29]
Adopted system/ Principles	Social responsibility—public institutions	A mixed responsibility system—government and private responsibility
Contribution source for benefits	Tax based on SAT	Work accidents: private insurance Occupational diseases: contributions to social security
Benefits[b]	Accident aid Sickness/disease aid Special retirement Invalidity pension Death pension to dependents	Incapacity aid Pensions Death benefits to dependents and related expenses Readaptation benefits Professional rehabilitation aids Aids to third parties

[a]The compilation is not exhaustive
[b]Simplification of Portuguese Law nº 98/2009 [29] (article 47 and others)

system is unified, which contrasts with the Brazilian system, which is defined in multiple legal instruments. A comparison is shown in Table 1.

The rules on the organization of OHS services differ significantly in terms of requirements and dimensions. In Brazil, the staff performing OHS services in companies is defined by NR 4. In Portugal, the accreditation of OHS professionals is attained by registration with the ACT and by holding a Certificate of Professional Competence (CCP), which is valid for five years.

The total accident and fatality rates are expressed per 100,000 workers for a period of ten years (Fig. 1). The first conclusion from this comparison is that Portugal presented much higher rates of total accidents and much lower fatality rates than Brazil. For Brazil, only registered workers were considered for calculation of the index. Considering that about half of the population engaged in economic activities is in the informal sector, the results are not fully representative [5].

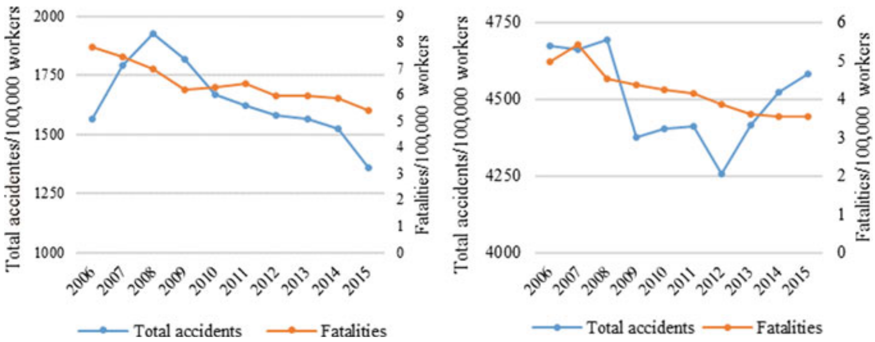

Fig. 1 Total accidents and fatalities per 100,000 workers in Brazil (left) and Portugal (right). *Source* Elaboration based on Pordata [6] and AEAT [31]

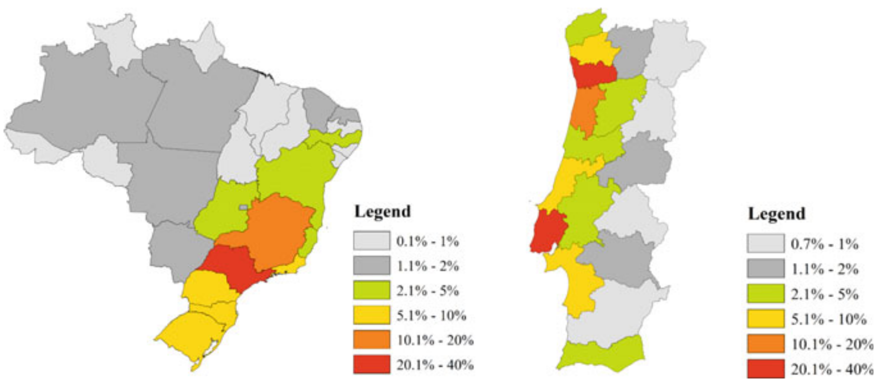

Fig. 2 Average of total work-related accidents per state in Brazil (left) and per district in Portugal (right) in 2014 and 2015. *Source* Based on Previdencia [30] and GEP/MTSSS [7]

The characterization per state (Brazil) and per district (Portugal), Fig. 2, shows a prevalence of accidents in the south and southwest regions in Brazil and the districts of Lisbon, Porto, and Aveiro in Portugal. A characterization by economic sector demonstrates that the incidence of accidents in both countries is more related to the tertiary sector [7, 30].

The data on fatalities by economic sector were also considered for 2014 and 2015. In Portugal, the mortality rates by economic sector were, respectively per year: 11 and 19% in the primary sector, 61 and 44% in the secondary sector, and 28 and 36% in the tertiary sector. In these years, in Brazil fatal accidents corresponded to 9% in the primary sector, 37% in the secondary sector, 53% in the tertiary sector and 3% were not classified.

A comparison of the consequences of work-related accidents and occupational diseases is difficult due to differences in the compensation criteria. In Brazil, the total amount related to compensation for work-related accidents and diseases are disclosed on a yearly basis in national databases [32]. For Portugal, costs of compensation for work-related accidents and occupational diseases were not found. However, data from the ASF [33] provides information on the number of insurance policies for work-related accidents and the total monetary value associated with premiums, operating costs, claims costs and technical provisions.

A comparison of the prevalence of occupational diseases was not possible due to the absence of official databases on this theme in Portugal. However, the existing information suggests that musculoskeletal conditions are the most reported and certified work-related diseases in both countries [34, 35].

4 Conclusions

Brazil and Portugal have important social, cultural and economic interactions, resulting in various agreements established in recent years to facilitate the exchange of professionals. However, there are relevant aspects of OHS that should be brought to the attention of decision-makers, investors, and professionals.

Both countries have a complex array of legal requirements in the OHS field. Brazil has technical rules that can be said to be clearer and more transparent than those in Portugal. Regarding the compensatory system, the Portuguese structure is more robust, presenting a more comprehensible structure that clearly defines the financing system, the supportive measures to be adopted, and the institutions that are involved in the compensation process.

Even though OHS has received a much higher priority in recent years, several gaps remain in both countries. Brazil and Portugal have poor databases of the main aspects of occurrences, their frequency, and consequences. More detailed databases are necessary to allow the development of efficient strategies from governments and other stakeholders. Future studies should investigate the influence of other factors, such as the promotion of a safety culture and intensification of inspection actions and other influential parameters, such as economic aspects.

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Relation Between Vibration/Noise with the Type of Surface, in Light Vehicles. Use of Data as a Tool to Study the Health Impact of Drivers

Marco Ferreira Dias and Maria Luísa Matos

Abstract Every day a huge number of light vehicles travels daily by road, and is drivers are subjected to the conditions of the surface of road. The objective is to study the relation between vibration/noise with the road condition and if the data can be used to develop a management tool in the maintenance of urban pavements by collect and process data related to vibration and noise in a defined path with different types of road and irregularities. By the data obtained (vibration and noise) evaluate the exposure risk of the driver. A course was defined, and tests were performed using a sound level meter and an accelerometer to obtain the necessary data for the intended interpretation. The selected route is located within Oporto district and was carried out in a schedule with little traffic circulation to avoid traffic queues. During the data collection, it was possible to verify, both in vibration and in noise, some of the irregularities observed during the tests. In terms of the vibration/noise ratio, it is verified by the interpretation of the values that it exists although there is variation in the values obtained for the same type of irregularity. The results obtained in tests, and in particular the lack of results in relation to noise analysis within the vehicle, as well as the relationship noise/vibration, give rise to a need to develop a more in-depth study on the subject considering the absence of studies on the relation vibration/noise as a way of detecting the degradation of the roads and the development of a management tool.

Keywords Vibration · Noise · Light vehicle · Maintenance · Urban pavement

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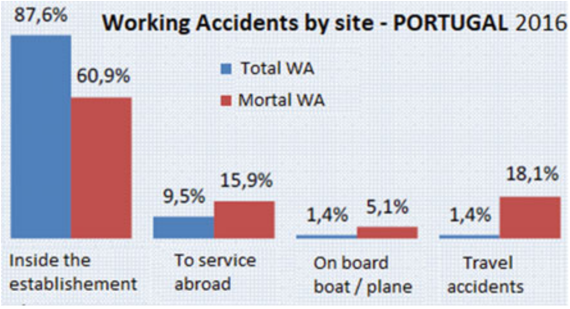

Fig. 1 Working Accidents by site (Portugal, 2016)

1 Introduction

In 2016, 87.6% of the total number of work-related accidents occurred during the work period, and only 1.4% were traffic accidents during working hours. However, the traffic accidents reveal a high level of severity, since it was responsible for 18.1% of fatal accidents (Fig. 1) [1].

The vehicles when moving along the roads are dynamically excited by the variations of the elevations of the road profile and, as a result, the vibrations are transmitted by the vehicle body to the occupants. The discomfort that drivers feel due to these vibrations is one of the key elements in the perception of velocity and its choice. In fact, it is common sense that drivers choose different speeds related to the level of vibration they feel due to the dynamic interaction with the road surface profile [2, 3].

2 Noise as a Source of Noise Pollution

The ability of a vehicle to generate noise depends not only on the type of engine used and its components (transmission quality and exhaust systems, braking, intake and cooling (fans), aerodynamics of the body) but also on the interaction between the tread and tires [4], since a major contribution to traffic noise is the noise caused by tire/road interaction, especially above 40 km/h, in all driving conditions [5].

3 Vibration as an Element of Safety

The speed reached by the vehicles is one of the main parameters to describe the behavior of drivers [6, 7], however, it must be recognized that the speed that drivers reach is affected by several factors, and the vibration inside the vehicle can play a very important role. Most of today's speed reduction measures are based on the level of vertical vibration perceivable by the driver and this is based on the dynamic interaction between the vehicle and the road [8]. On the other hand, these vibrations must be carefully monitored and controlled because they are a fundamental parameter in pavement monitoring systems, since they influence driving comfort, pavement damage [9, 10] and vehicle maintenance costs [2, 3].

4 Maintenance of Urban Pavements

There are multiple defects in urban pavements, including various types of surface deformations, irregularities and patches. If the pavement is not repaired in time, the repair costs increase significantly as the pavement deteriorates. A deterioration model of the road is the key element in the establishment of road maintenance management systems. The review of maintenance strategies in cosmopolitan cities, particularly in developed countries, indicates that the implementation of urban pavement maintenance systems has several limitations with regard to long-term maintenance plans. This is due to the lack of enough understanding of the pavement deterioration pattern [11]. In deformation, when a vehicle circulates on an uneven surface as a result of the dynamic interaction, dynamic forces are transmitted vertical to the pavement and vibrations are generated inside the vehicle. Several studies have pointed out that vertical dynamic forces greatly reduce the useful life of the pavement because they can accelerate the degradation of the pavement [9, 10, 12].

5 Materials and Methods

The research was conducted between September and December 2017, through the databases showed in Table 1. The combination of keywords used were: Vibration + “Light Vehicle”; Vibration + Maintenance; Vibration + “Urban pavement”; Noise + “Light Vehicle”; Noise + Maintenance; Noise + “Urban pavement”; “Light vehicle” + Maintenance; “Light vehicle” + “Urban pavement”; Maintenance + “Urban Pavement”. The search for the various combinations was analyzed in all the databases in the SUBJECT field, using the Boolean operator “AND”. Articles are considered eligible if they meet the following pre-requisites:

- Articles available in full-text;
- Articles available in English, Portuguese of Portugal or Portuguese of Brazil;
- Articles that address urban pavements, light vehicles, vibrations inside the vehicle, vehicle-generated noise for your occupant.

All the identified studies were initially selected by the title and abstract, and then the whole texts were analyzed. The methodology used to treat the data and

Table 1 Maximum and average speed, duration and distance

Test	Max. speed (km/h)	Aver. speed (km/h)	Duration (hh:mm:ss)	Distance (km)
1	116.9	51.3	00:36:25	31.10
2	125.5	59.4	00:31:25	31.11
3	120.9	50.6	00:35:20	29.81
4	123.5	52.4	00:35:37	31.10

organization of the systematic review was based on the PRISMA Statement[1] methodology [13].

Data collection was performed using a Sound level meter 01 dB Blue Solo from 01 dB Metravib, placed near the most exposed driver's ear (considered to be the right ear) to monitored occupational noise and two accelerometers SVANTEK, connected to a vibration analyzer model SV106, were used for measurements, simultaneously, vibrations magnitude on seat and vehicle's floor. Continuous data were downloaded and analyzed using two software's. First was dBTrait 5.1 and it was used to analyze occupational noise, second was SVAN PC ++, version 3.1.1 of SVANTEK to analyze vibrations. The vehicle used was a MINI, model COOPER D of 2014 with automatic transmission, and the test was carried out on the public road of the district of Porto.

In order to perform the tests to obtain the data, the route shown in Fig. 2 was chosen, starting at Praceta Francisco Borges in Paranhos, entering the A3 until the exit to the A41 towards Maia, leaving towards Nogueira da Maia, contour of it and realization of the inverse course to the place of departure.

This course was carried out 4 times, and the velocity in each of the tests was variable (ranging from the minimum of 116.9 km/h corresponding to test 1 to the maximum of 125.5 km/h corresponding to test 2—see Table 1).

During the tests, there was a concern to eliminate as much as possible all the variables that could influence the results, always carrying out the same course on the same day with the same driver, the same vehicle, similar atmospheric conditions and the same traffic conditions.

For the accelerometer, the position of the axes was considered NP ISO 2631-1: 2007 [14], with axis 1 corresponding to the X axis (front/rear), axis 2 corresponds to Y axis (lateral movements) and axis 3 corresponds to the Z axis (vertical movement). As for noise measurement, a bag was used to place the sound level meter inside it, and it was placed around the driver's seat so that the microphone was a maximum distance of 10 cm from the right ear of the driver.

To evaluate the effect of vibration transmissibility on the seat surface, SEAT (Seat Effective Amplitude Transmissibility) parameter will be used. This translates the ratio between the weighted acceleration values obtained for the z axis, respectively, on the seat and on the floor of the vehicle.

[1]http://www.prisma-statement.org/ (accessed in 21/09/2017).

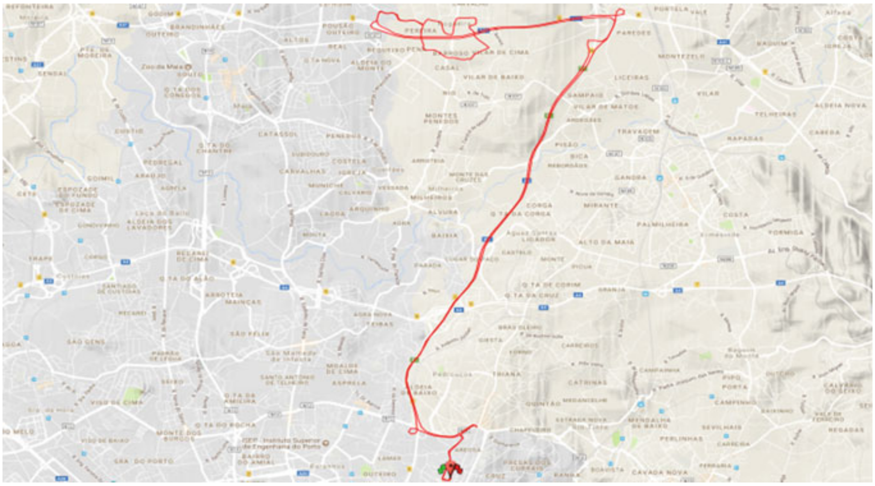

Fig. 2 Total distance traveled

A total of 153647 results were identified, and the results of the research are presented in Table 2.

Regarding Fig. 3, 26 results were eliminated because they were repeated. 11 articles that met the pre-established requirements for this systematic review were considered eligible. Of the results not considered, 153,556 were excluded because they did not fulfill the basic requirements. The results considered for an integral study were only 6 since 5 of those considered eligible, after a comprehensive and careful analysis, did not fit the proposed theme. It is also presented in Fig. 2, the overall structure of the research based on the PRISMA methodology [13].

The articles considered eligible describe tests on the estimation of noise caused by vehicle circulation and the type of road in which they circulate, data collection methods for pavement maintenance, and the influence of the road type on the behavior of the drivers.

6 Results and Discussion

According to Chandra, Abagnale and D'Apuzzo [3, 9, 10, 12], a vehicle when circulating on an uneven surface (created by various defects in urban pavements including various types of surfaces such as drainage boxes and water and telecommunications systems transmits vertical dynamic forces on the pavement and vibrations are generated inside the vehicle. In Shukla's opinion [4], in addition to the noise generated by the vehicle from all its mechanical and aerodynamic components, this author says that the noise also comes from the interaction between the tread and the tire of the vehicle. By the graphs obtained in the tests carried out and

Table 2 Search results by resource

Summary of selected articles	Sum ma ry of articles collected	Summary of rej ected articles	Summary of total rejected items					Data base
			Date	Doc. type	Source type	Language	Out of theme	
91	153,647	153,556	107,343	22,924	463	510	22,316	SUM
21	122,50	12,229	8859	1825	69	233	1243	SCOPUS
10	8394	8384	6395	145	7	36	1801	Academic Search Complete
15	2635	2620	1541	10	0	5	1064	Web of Science
6	29,040	29,034	22,888	4126	0	0	2020	Emerald Full Text
5	249	244	164	3	0	0	77	Inform aworld
0	787	787	528	0	0	0	259	SAGE
0	56	56	32	0	0	11	13	SciELO
8	89,077	89,069	59,721	15,638	0	59	13,651	Springerlink
3	647	644	426	16	0	2	200	Wiley Online Library
14	6479	6465	4379	725	0	161	1200	Inspec
8	1343	1335	682	61	0	3	589	Science Direct
1	2690	2689	1728	375	387	0	199	IEEE xplore

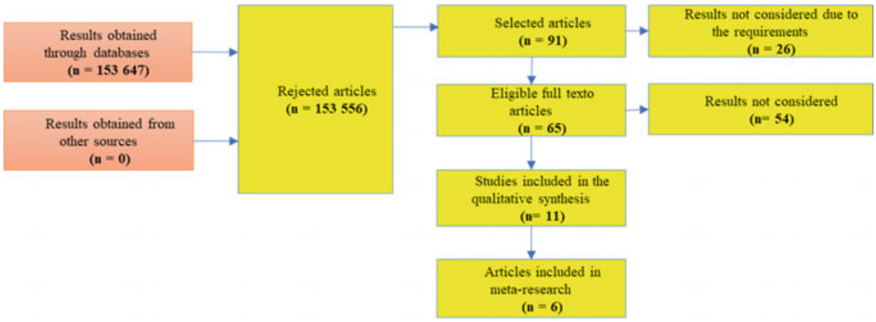

Fig. 3 Search result (based on PRISMA methodology)

according to Sadeghi [15] there is indeed an appearance of vibrations within the vehicle created by the various irregularities detected.

As an example, Fig. 4 shows the graph of irregularities in the acceleration spectrum, and Fig. 5 shows the graph of the irregularities identified in the noise spectrum obtained in the first test.

Under Article 3 of Decree-Law nº. 46/2006 of February 24 [16], the exposure limit value and the exposure action value are, respectively, 1.15 and 0.5 m/s^2. In Annex II [15], the method for determining the driver's exposure to vibrations is given by Eq. (1), whereby the values of **k** are defined for the respective axes x, y and z:

$$A_{(8)} = ka_w\sqrt{\frac{T}{T_0}} \tag{1}$$

Taking the values of the duration of the test (Table 1), as the exposure time (T), and the remaining values of the ANNEX II we have (Table 3):

Considering that vibration measurements have been made using the six channels of the vibration analyzer, it is also possible to determine the effect of vibration transmissibility on the seat surface. Thus, to evaluate the dynamic behavior of the seat, the vibration transmissibility was studied based on the SEAT.

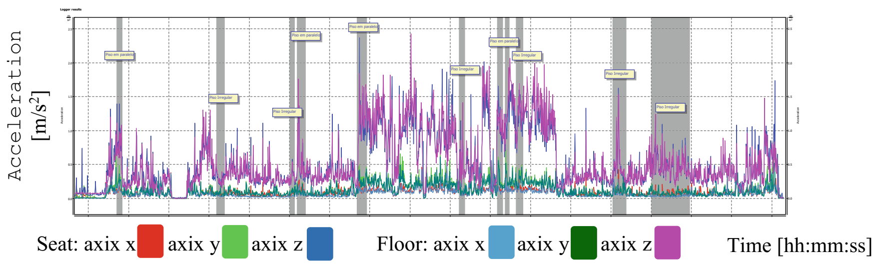

Fig. 4 Irregularities detected in the acceleration spectrum

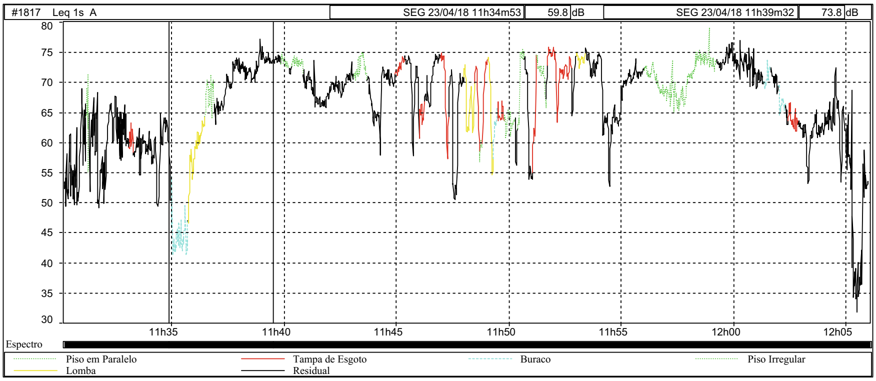

Fig. 5 Irregularities detected in the noise spectrum

Table 3 Partial values and total value of daily exposure to vibrations (A_8)

Partial A(8)	Ch3 [m/s²]	Time (s)	aw [m/s²]
1st TEST	0.1453	2185	0.527514
2nd TEST	0.1446	1885	0.565397
3rd TEST	0.1439	2120	0.530408
4th TEST	0.1389	2137	0. 510004

Workstation		
A(8)	0.3	m/s²

The values obtained in the accomplishment of the 4 tests, present values lower than 100%, reason why the acceleration measured in the floor is superior to the acceleration measured in the seat which means that it has an attenuating effect in the transmission of vibration (Table 4).

The obtained result in the noise measurements for the 1st test is 70 dB(A), for the 2nd test is 69.8 dB(A), for the 3rd test is 69.6 dB(A) and the 4th test is 69.4 dB (A), and the result for $L_{EX,8h}$ is 64.3 ± 1 dB(A). The noise generated by the various irregularities is below the exposure limit defined in Article 3 of Decree-Law nº. 182/2006 of September 6 [17].

Table 4 Values relative to the SEAT parameter

SEAT parameter (average values)		
Test 1	98.52%	Attenuates
Test 2	98.58%	Attenuates
Test 3	98.83%	Attenuates
Test 4	97.59%	Attenuates

7 Conclusions

Regarding the vibration/noise ratio, due to the many variables involved, the data did not allow to establish a relation between the irregularities and the vibration/noise because of the difficulty to registrant the irregularities by the minute instead by the second. For example, it's possible to obtain 63.4 dB (A) for a hole, 62.8 dB(A) for a spout, or 63.7 dB(A) for a sewage cap making it impossible to differentiate between them. The same is true for vibration. It's possible to get very close values for different irregularities. As an example, it's possible to have 1.0471 m/s^2 in a_{wz} for a sewage cap and 1.0839 m/s^2 in a_{wz} for a hole.

However, the state of the urban pavement was not the only concern of this study, because, considering that the vehicle is widely used as a work tool, there was also the concern of analyzing the driver's exposure to noise and vibration levels. For the time mentioned in Table 3 for the four tests, and considering that they are a single activity, it is concluded that the worker exposure (A_8 = 0.3 m/s^2) is below both the exposure limit value (1.15 m/s^2) and the exposure action value (0.5 m/s^2). In relation to noise, the value of $L_{EX,8h}$ = 64.3 ± 1.0 dB(A) is also below the exposure limit value $L_{EX,8h}$ = 87 dB(A) and the values of higher action ($L_{EX,\ 8h}$ = 85 dB(A)) and lower action ($L_{EX,\ 8h}$ = 80 dB(A)).

It is concluded, therefore, that the noise and vibration values obtained in the tests are within the parameters allowed by the Portuguese legislation, and therefore do not present any risk situation for the worker to carry out a driving activity, considering the limitations of this study (only one car, in a defined path and during one summer day).

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Work-Related Accidents in Urban Solid Waste Collection

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Abstract The activity of urban solid waste collection is fundamental for the preservation of the public health. As the demand for waste collection increases, so does the number of professionals involved. The objective of this study was to identify and analyze the main causes of work-related accidents in the activity of urban solid waste collection. For this purpose, first was carried-out a literature review in CAPES, Scopus and Google Academics. Further-on, the data from two enterprises were analyzed. The results include 6 studies with 473 accidents and two enterprises with 756 and 189 accidents. The analysis shows that falls and sharp materials combined represent from 52% (enterprise A), 55% (enterprise B) to 70% (literature review) of all causes of accidents. Further studies should be conducted in order to give practical solutions for improving occupational safety and health of workers in the area.

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Keywords Accidents · Falls · Sharp materials · Waste collection · Safety at work

1 Introduction

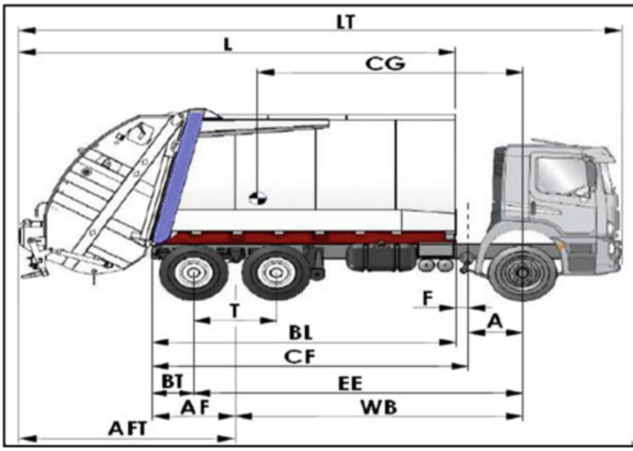
According to the Brazilian Association of Public Cleaning and Special Waste Companies [1], from 2003 to 2014, Brazil had a 29% increase in waste production, where more than 41% of the 78.6 million tons of solid waste generated in the country had as its final destination the open dumps or controlled landfills, which is an inadequate form of disposal, classifies by the National Solid Waste Policy [2] as an environmental crime which is punished with a fine that can reach R$ 50 million. Approximately 78 million Brazilians, corresponding to 36.4% of the population, still don't have access to a good quality service of the collection of waste, bringing consequences for the public health. The waste generated in Brazil in 2016 was 214,405 tons/day, from which only 196,452 tons/day were collected. In the same year, the urban solid waste collection generated around R$ 27.3 billion.

The National Solid Waste Policy [2] and the Brazilian Standard—NBR 10,004 [3] define the term "solid waste" as a waste resulting from activities of industrial, domestic, hospital, commercial, agricultural, service and sweeping origin. Included under this term is the sludge from water treatment systems, those generated in pollution control equipment and facilities, as well as certain liquids whose peculiarities make it unfeasible to be dumped in the public sewage system or bodies of water, or require technically and economically unfeasible means in the face of the best available technology.

Solid waste presents a wide diversity and complexity, and its physical, chemical and biological characteristics vary according to the source or activity, and can be classified according to NBR 10,004 [3], such as:

- Class I (hazardous)—are those that represent dangerousness or characteristics of flammability, corrosiveness, reactivity, toxicity and pathogenicity. In this case, they are residues that present risks to public health and the environment.
- Class II (non-hazardous)—are divided into two types:
  (a) No Inertes (known as Class II A)—this type of waste includes the residues of domestic origin. This solid waste was investigated in this study.
  (b) Inertes (known as Class II B)—this type of waste undergo the solubilization tests and do not exceed water solubility standards. In this way, the water remains potable even after contact with the waste.

Based on Law No. 11,445 of 2007, urban cleaning and solid waste management is the set of activities, infrastructures and operational facilities for collection, transportation, transshipment, treatment and final destination of household waste and garbage originating from the sweeping and cleaning of public places and streets [4].



	mm	inches
A	1115	44
F	-115	-5
BL	4550	179
CF	4435	175
L	6582	259
EE	4930	194
BT	620	24
WB	4310	170
AF	1240	49
AFT	3272	129
T	1240	49
LT	9093	358

Fig. 1 Standardized compactor

According to the Brazilian Association of Solid Waste and Public Cleaning [5], the standardized compactor used in Brazil follows the dimensions described in Fig. 1.

The compactors are rear loaded, have a grille-type stirrup, 500 mm from the ground, with a width of 410 mm and a front stop for the feet of 60, 200 mm wider on each side.

The cleaning and the collection of waste is considered as an essential public service by law [6]. During this process, it was noted that overwork is the main problem in the profession of waste collection, since waste collectors' work long working hours with long journeys and accelerated pace, favoring the probability of a work safety accident [7]. The specific safety Regulatory Norm (RN) of the Ministry of Labor and Employment (MTE), referring to the urban solid waste service is currently under public consultation through the *Portaria SIT 609 of 2017* [8]. Once approved, this norm will give recommendations regarding environmental conditions and improving occupational safety and health. While it is not approved, compliance with the safety standards is done through the other current NR, among which it is possible to mention: the NR 01—General Provisions; NR 03—Specialized Services in Safety Engineering and in Occupational Medicine; NR 04—Specialized Services in Safety Engineering and Occupational Medicine—SESMT; NR 05—Internal Commission for the Prevention of Accidents—CIPA; NR 06—Personal Protective Equipment—PPE; NR 07—Medical Occupational Health Control Program—PCMSO; NR 09—Environmental Risk Prevention Program—PPRA; NR 11—Transportation, handling, storage and storing of materials; NR 12—Safety in Machinery and Equipment; NR 15—Unhealthy activities and operations; NR 17—Ergonomic; NR 21—Outdoor work; NR 22—Occupational safety and health in mining; NR 24—Sanitary and comfort conditions in the workplace; and NR 26—Safety signs.

In the NR 15, attachment 14 (Biological Agents), it is contemplated that the activity of urban waste collection should be considered as a maximum unhealthiness degree [9] for collecting and industrialization, posing a risk of contact with biological agents, since during the exercise of the activity the worker may be exposed to human waste, and even to piercing and cutting materials containing human biological material, being a source of contamination by infectious diseases.

Additionally, the Brazilian Technical Norms—NBR, which deal with aspects applicable to the urban cleaning service, in their text, bring contributions to work safety and health, such as NBR 14,599, dated October 24, 2014, which establishes the safety requirements for mobile equipment, solid waste, rear and side-loading. In 2015, an errata of the respective standard was published, with the objective of adapting items 6.2.8 and 6.2.9 [10], thus defining:

6.2.8. It is recommended to carry-out the reverse operation with the assistance of the outside operating personnel whenever it is possible.
6.2.9. Ensure that no person travels in the equipment load compartment.

The Brazilian Traffic Code, established by Law no. 9503 (1997), provides in its art. 235, that it is prohibited to transport people on external parts of vehicles of any kind [11]. In this way, there is an observance regarding the aspects related to the safety of people with regard to the risk of falling and being run over.

Therefore, the objective of this study was to identify and analyze the main causes of work-related accidents in the activity of urban solid waste collection.

2 Methodology

In order to identify the main causes of work-related accidents in urban solid waste collection services, the methodology comprised of two parts: to conduct a literature review, and to analyze enterprises data.

The literature review was carried-out in 2018, following the guidelines of *PRISMA—Preferential Report for Systematic Reviews and Meta-analyzes* [12]. The searching was conducted by using the Brazilian platform CAPES and Google Scholar. Two screening strategies were applied. In the first searching strategy, the screening was conducted by using the Brazilian platform CAPES and Google Scholar by using the keywords *"Work accident", "Solid waste", "Urban cleaning"* and *"Garbage collection"* with the Boolean descriptor *"OR"* and *"AND"*. In the second searching strategy, the screening was conducted in Google Scholar, using the keywords *"Sharp materials"*, *"accidents"* and *"urban cleaning"* with the Boolean descriptor *"OR"* and *"AND"*.

In both searching strategies, after the identification process, the studies were excluded if published in other language than Portuguese, and then screened and excluded by title. Finally, remained studies were read thoroughly and excluded if not using quantitative analysis of occupational accidents in urban solid waste collection, in particular household waste collection. The studies from other countries were excluded due to having different standards and using different methodology (for example different model of compactor truck used in the study).

The work-related accidents were analyzed from the reports of occupational accidents of two enterprises (*"A"* and *"B"*) dealing with urban solid waste collection service. The enterprises were located in the metropolitan region of Recife, capital of the state of Pernambuco, Brazil. The number of employees varied throughout the considered period, where for enterprise *"A"* the variation was from 3380 to 3859 workers from 2014, 2015 and 2016, while for the enterprise *"B"* it was 2020 employees in 2017. The two enterprises act in the same region and are regulated by same legislation, conducting activities of urban solid waste collection service, where were considered in particular accidents which occurred during household waste collection, therefore it was concluded that conditions were similar and possible to compare with each other. The causes of accidents were analyzed in accordance with the causes encountered from the review of previous studies.

3 Results and Discussion

The literature review resulted in the identification of 2886 studies, where 1666 resulted from the first searching strategy, and 1220 from the second. After the exclusion by language and screening by title, 1649 studies were excluded from the fist and 1210 from the second searching strategy. Therefore, a total number of 27 studies were read thoroughly (17 studies from the first and 10 from the second searching strategy). After considering only studies in accordance with the objective and defined inclusion criterion, a total number of 6 studies [13–18] were included in the review analysis (3 studies from the first and 3 from the second searching strategy). The included studies were conducted in the states of Rio de Janeiro (2), Bahia (1), Federal District (1), São Paulo (1) e Paraná (1). Two of the included studies considered public enterprises from Rio de Janeiro [13] and [14], while other four studies were conducted in private enterprises [15–16].

The causes of accidents varied depending on the study. The causes considered only in one study were *Training, Low Personal Protective Equipment (PPE) quality, Absence of PPE/Collective Protective Equipment (CPE), Deviations, Lack of attention,* and *Electric shock*. The causes considered by two or three studies were *Foreign body in the eyes* and *Traffic*, while causes considered by four and five studies represent the *Compactor operation, Falls from the truck, Excessive effort* and *Sharp materials*. As illustrated in Fig. 2, the number of accidents increased as it increased the number of studies which considered the cause.

In total, the studies considered 473 accidents, from which 45.03% were caused by sharp materials and 25.37% by falls. These two causes represent 70.40% of all accidents registered in the urban solid waste collection service. The following Fig. 2 presents the indices found in each study and the sum of them divided by cause.

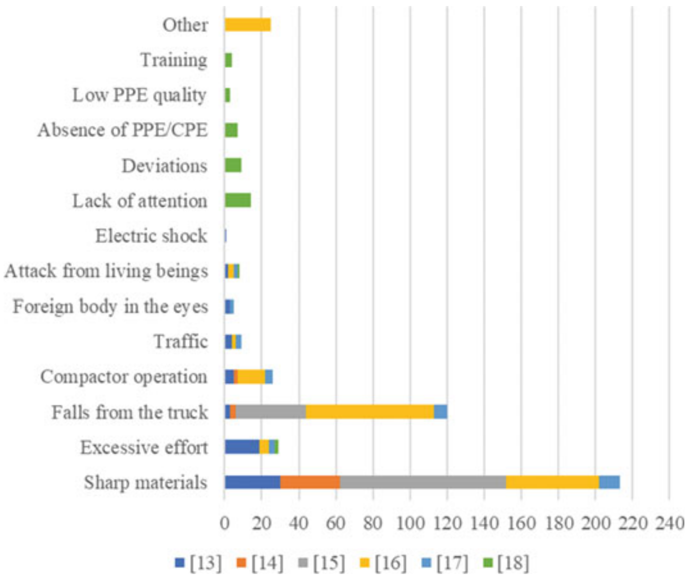


Fig. 2 Literature review—cause of accident

The same analysis was applied to the data of work-related accidents from enterprises A and B, which were considered to be comparable with the results from the review, as all included studies are originating in Brazil, utilize a rear-loading compactor and have the same legislative and normative requirements to follow and apply.

The enterprise A registered a total number of 756 accidents during three years (252 accidents/year), while the enterprise B had 189 accidents. As it is illustrated in the Fig. 3, sharp materials and falls also presented high indices. In the enterprise A, sharp materials caused 25.15%, while in B it was 27.00%.

While the Fig. 2 presents *Excessive Effort* with high indices, the Fig. 3 elaborated from data of the enterprises show less concern in relation to this cause (2.00 and 4.68%). The other three main causes identified in Fig. 2 (*Falls, Compactor operation* and *Sharp materials*) were also found to have high indices in enterprises A and B. Additionally, the enterprises suffered high indices of accidental causes in *Stumble/Slippery* (17.50 and 6.43%), *Affected by object/tool* (10.00 and 16.96%) and *Traffic* (7.50 and 12.28%) for the enterprise A and B respectively.

Further on, it could be seen from Fig. 3 that the enterprises A and B separated the *Stumble/slippery* cause from the cause of *Falls from truck*. These two causes of accidents could be combined into one bigger group "*falls*", giving the total sum for enterprise A = 27.48% and enterprise B = 28%. Both of those percentages seem to be in accordance with the results of previous studies illustrated in Fig. 2 (falls 25.37%).

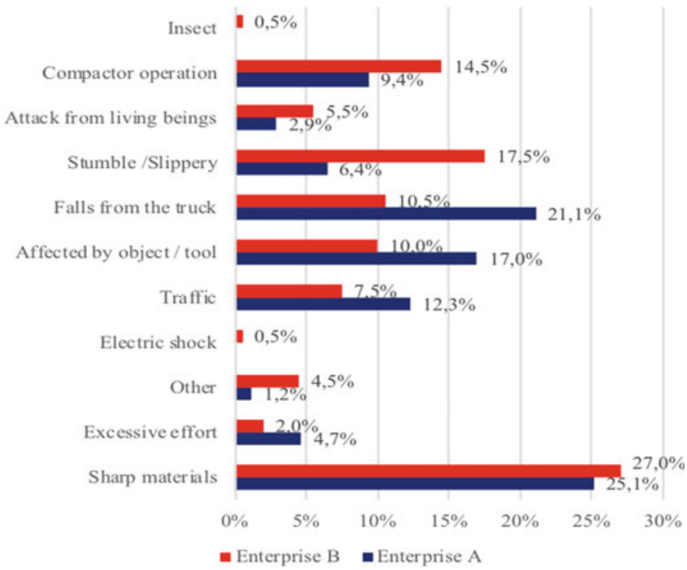


Fig. 3 Enterprises A and B—cause of accident

The *Sharp materials* as the causes of accident from enterprise A = 25.15% and B = 27.00% were much lower than it was observed in previous studies illustrated in Fig. 2 (*Sharp materials* 45.03%). Anyway, it seems that it can be concluded that resolving these two causes of accident would significantly increase the safety and well-being of workers in the area, representing a total of causes of 70% by previous studies, 52% by enterprise A, and 55% by enterprise B. In total, 1418 accidents were analyzed, including 473 from the studies in the literature review and 945 from enterprises A (756) and B (189). Accidents due to falls occur due to the condition of roads and the frequent movement that worker has to perform during the collection. Further on, accidents due to sharp materials are related to non adequately stored waste and to direct contact of the collector with waste, where in some cases the safety glove does not protect in its entirety, which could potentially result in infection by the biological agent.

A specific safety regulatory norm for urban solid waste service is currently under public consultation. In the mid time, the risks identified through this study could be successfully managed by using existing Brazilian safety regulatory norms. The Brazilian labor safety legislation and the existing technical standards establish actions aimed at the main accident rates in this sector. They advocate the safety procedures, the use of CPE and PPE and give to the workers the right of the additional category of insalubrity and prohibit the transportation of people on external parts of vehicles. Future studies could analyze the differences in causes of accidents between public and private urban solid waste collection enterprises.

4 Conclusions

As it can be concluded from this study, there are various causes of accidents, which should be considered in order to provide adequate occupational safety and health conditions for the workers participating in the urban solid waste collection.

The literature review shows that the main causes of accident were related to the *Compactor operation,* the *Falls from the truck, Excessive effort* and *Sharp materials*. From those four, *Sharp materials and Falls* represented 70% of all causes of accidents.

The data analyzed from enterprises A and B show that the main causes of accidents were related to *Affected by object/tool, Traffic, Falls and Sharp materials*. From those four, *Sharp materials* and *Falls* represented 52% in enterprise A and 55% in enterprise B.

Future studies should focus on giving practical solutions for at least two most influential causes of accidents (*falls* and *sharp materials*).

The existing standards provide recommendations for the main accident indicators identified in this sector. It is in public consultation a specific regulated norm for the urban solid waste collection service, which should improve working conditions. It recommends the implantation of a container, where this measure tends to reduce accidents with sharp materials and falls, because it reduces the number of times that the worker gets directly in contact with the waste and the embarking and disembarking of the truck compactor.

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Virtual Reality Applications in the Extractive Industry—A Short Review

J. Duarte, M. Lurdes Dinis and João S. Baptista

Abstract The mining industry presents itself as one of the sectors with major occupational accidents, being only surpassed by agriculture (including fishing) and forestry (including hunting). The technology development has been improving safety awareness and working practises; one of the most used tools is virtual reality (VR). The PRISMA Statement methodology was applied in order to find evidence of these new technologies in the extractive industry. For that, a set of keywords related to both topics (mining and VR) was defined, and the main journals and databases in the engineering field were screened. After applied both exclusion and inclusion criteria, the 1786 papers were reduced to eight. The results show that this resource is useful, however, when comparing to the application in the construction field, in what concerns to safety management, there is still a lot to achieve.

Keywords Mining industry · Virtual reality · Computer applications

1 Introduction

Mining, being considered a high-risk industry, presents itself with great technical challenges, which, in its turn, result, very often, in environmental and social impacts [1, 2]. The high incidence of accidents (and fatalities) is often linked with inappropriate or ineffective training Materials and methods [3, 4], as well as inability of

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perceiving and recognising hazards [5]. In the United States of America[1] (USA) and 2017 alone, 28 fatalities occurred. In Portugal,[2] considering the same year, three deaths occurred and eight occupational accidents happened. Due to its complex nature, a great deal of training is required, in order to ensure safety while operating. However, most of the training tasks (such as escaping from disasters and mine rescue) cannot be practised in the real world, introducing virtual reality as a suitable technology to overcome this problem [1].

Virtual Reality (VR) is a broad term used to refer to a real-time, real-world computer simulation, in which subject behaviour and object interaction are key elements [6]. This concept was brought up over fifty years ago when the first immersive human-computer interaction (HCI) mock-up entitled "Man-Machine Graphical Communication System" was invented [7]. VR has already been shown to be a useful tool in various fields, such as medicine, military, real estate, architecture, aviation, forestry, construction, among others [2, 3, 5, 7]. Nonetheless, this technology can only provide a limited level of "realism", since the perceptual and cognitive viewpoints are hard to accommodate due to a lack of sensory feedback [7]. In 2003, Burdea & Coiffet first introduced the five basic components of a VR system, that are: engine, software and databases, input and output devices, user and tasks. Amongst them, and focusing mainly in the mining industry, input/output devices are considered the most import ones since they are the only way through which the users can sense and interact with the environment [1]. Amidst all its capabilities, VR can also work as a simulator, enabling users to move around and act in three-dimensional representations [3]. In fact, some evidence provided by Mallett & Unger [8] shows that VR offers great promise to the extractive industry, being the sharing of mining operations data, visualisation of unseen and buried ore bodies (or even gas seams), training simulations and high-risk tasks practising without exposing the operator to any actual danger. Van Wyk & Villiers [6] suggested that due to VR features, it could be an e-training tool, referring to the facility to simulate hazardous situations more frequently than would be encountered in the real world and to simulate situations that have not previously occurred in real ground, but could still be encountered. The control of mine operations through a safe an effective way can also be achieved using satellite and terrestrial links of communication. Kizil [3] points MineStar, developed by Caterpillar, Mincom and Trimble, which combines the mining software with the Global Positioning System (GPS), with the aim of monitoring both equipment and mining operations. Another approach to improve safety performance can be investigating accidents by reconstructing them; that may lead to a better understanding of how the accident took place and, more importantly, how it could have been prevented [3]. Nowadays, VR main challenges and limitations are performance evaluation, implementation and

[1]https://www.msha.gov/data-reports/statistics/mine-safety-and-health-glance (accessed 9th May, 2018).

[2]http://www.act.gov.pt/(pt-PT)/CentroInformacao/Estatistica/Paginas/NotaPrevia.aspx (accessed 9th May, 2018).

workers adaptability to the used devices [7], although personal characteristics are also being considered in the main equation [9].

The main objective of this research is to find evidence of virtual reality applied in the context of safety management, in the mining industry.

2 Methodology

In order to conduct this short review, Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA Statement) were used. The research included some of the main multidisciplinary databases and journals such as Academic Search Complete (ASC), Cambridge Journals Online, Current Contents, Emerald Insight, Scopus and Web of Science, as well as engineering databases and journals, Association for Computing Machinery (ACM), Geological Society of America (GSA), IEEE Xplore, Inspec, Institute of Physics (IOP), SAGE Journals, Science Direct, Springer and Taylor and Francis. The search was conducted, whenever possible, in the title, abstract and keywords, using a keywords sentence to limit the study ("virtual reality" OR "augmented reality") AND (mine OR quarry OR "open pit" OR "open cast"). As screening criteria were considered only articles and articles in press, published between January 2010 and March 2018 and experimental studies published in journals and written in English. The articles had to be applied in the mining field using the VR technologies.

3 Results

From a total of 1786 identified articles, 804 papers were excluded by date. The second exclusion criteria applied was the type of paper: only experimental studies were considered, excluding 596 more articles. The paper source was also taken into consideration, leading nine more articles out of the study. Papers not written in English were also disregarded, which lead to the rejection of 34. Duplicates (13 articles) and works without full-text availability, after contacting the authors (11 articles) were removed after reading the title and the abstract, 290 articles that were not in accordance with the proposed objective were excluded. After this process, 32 papers were considered eligible and were full-text screened in order to determine the whole body vibration produced by various equipment used in the mining industry. The papers included in this study had to report VR in a mining industry context; eight papers met all the criteria.

From the eight assessed papers, seven of them reported VR as a training tool in the extractive industry, more precisely in coal mining [6, 9–14] and only one used VR as a teaching instrument [15]. A summary of the used technologies can be seen in Table 1, most of them being prototypes or simulation platforms and not appropriated or even licensed software.

Table 1 Used software per author(s)

Author	Software
van Wyk and Villers [6]	Look, stop and fix (prototype)
Linqin et al. [11]	Multi-agent based MAERB
Linqin et al. [10]	Simulation platform
Cai et al. [11]	Multi-agent simulation framework
Lei et al. [12]	3DMax modelling
Grabowski and Jankowski [13]	VR[a]
Chen et al. [15]	VR using projected 3D models
Cai et al. [14]	Multi-agent simulation framework

[a]with two hardware situations: (A) virtual gloves, vision-based tracking system and 2 different HMDs (low and high) (B) Razer Hydra controller and HMD with relatively low field of view

Van Wyk and Villers [6] investigated the requirements and constraints for VR training systems for the mining industry. In the first phase of the research, the authors conducted semi-structured interviews with safety, health and environment (SHE) managers and 43 workers (including belt attendant, miner, rock drill operator, panel operator, team leader among others). The authors observed the training methods developed and daily tasks, and distributed questionnaires after applying their hazard awareness training prototype, which made use of the participants' personal computers. The developed prototype ("Look, stop and fix") simulated underground working areas, integrating potential hazards (working in confined areas, handling heavy material and equipment, working in the proximity of a machine, and so forth) which had to be identified and approached with a corrective measure, in a game manner. Each correct answer would be scored, but if the participant failed to address the hazard, the consequences of it would be displayed. The results show that more than 80% of the subjects felt VR was a very successful way of training when comparing to the traditional methods such as videos or lectures, improving the safety culture, as well as the workforce awareness.

Linquin Cai et al. tried to build up a methodology for modelling risk behaviours [10], adding a risk accident analysis and prevention [9]. Then, in 2013 they attempted to implement fuzzy logic in the risk model they were developing. The authors finished their research by modelling the virtual miner's behaviours [14]. First, they developed a multi-agent environment for risk behaviour (MAERB) which the primary purpose was to train the miner's decision-making ability (when confronted with emergent situations). The primary results show that the model could successfully simulate a virtual environment for risk behaviour simulation. After having the prototype, the authors developed the system in a way that the users could configure the virtual mine, as well as the interactive man-machine interface attributes. The accident processes were reconstructed, and then the user was required to perform an interactive accident analysis. The results indicate that the proposed approach could effectively reconstruct and assist the accidents' risk analysis. Then, they constructed a behaviour model for the "virtual miner agent" which, for that, the authors used fuzzy logic: this model incorporated perception, motion control, internal states, behaviour and cognition. In addition to that, the model could adapt to external and unexpected situations, based on previous accident data from Chinese coal mines. To test this model, 20 students were recruited through email. According to the results, the emotion-model rated higher scores for believability than the random-model. In 2017, the authors included more type-behaviours such as fatigue and relief, leading to the same results as the previous one.

Lei et al. [12] tried to develop a rescue drill training system, using for that a 3DMax modelling software which was constructed upon a standardised drill script, based in rules and regulations. This facility used a mining model including all of the mining roadway layouts such as shafts, parking lots, refuge chamber, pumping stations, and so forth, being programmed in order to randomly change at some points (including the disaster points and environmental conditions) to ensure the exercise effect. The main objective was to improve the ability of quickly analysing the disastrous situations and act accordingly, reducing the demand on human resources, equipment and materials for emergency drills.

Grabowski and Jankowski [13] assessed different means of VR training in order to determine which suited best their country needs. For that, they recruited 21 miners, each one taking part in the two training simulations of blasting work.

In both simulations, the performed actions were: initial inspection of the blasting working area, removing the undetonated explosives, drilling blast holes, preparing explosives, and so forth; the only difference relied on the hardware. In situation A they used virtual gloves, vision base tracking system and antenna for image transmission allowing them to act as they were in the real world (highly immersive) and in situation B they used a joystick to navigate in the virtual environment—Razer Hydra controller (moderately immersive). Although the results show that both of the methods performed well, the highly immersive technology was easier and more intuitive to use. Most of the participants reported a positive effect on their own sense of knowledge and confidence on the field.

Chen et al. [15] studied the application of digital mining technology in a classroom teaching environment. Tests were conducted to determine the effectiveness of this method, involving mining modelling, production simulation and optimisation, having in consideration safety issues. Students could fill some knowledge gaps that persist between the theory and the field practices, receiving proper training and transferring what they learnt to the mining practice.

4 Discussion

In the mining sector and from the paper analysis, these new technologies are only being used for training purposes with regard to the safety module issue, in controlled environments. Demirkesen & Arditi [16] refer that a proper (safety) training may improve workers' conduct, at the same time it would lower accident rates.

Learning is considered an essential dimension of training and is regarded a preponderant factor in the improvement and sustainability of safety performance. Van Wyk & de Villiers [6] support the VR use with these purposes, once it has a flexible configuration, creating an opportunity to simulate a great variety of scenarios. The main advantage of such system is to expose workers to hazardous situations, which they could encounter in real life, without actually putting them into real harm. Their results showed that these training systems could provide appropriate levels of trainee interactions, allowing an easy problem area identification (in order to improve training programs). The feedback the authors got both from trainees and managers indicated that this system is viable and advantageous regarding the South African mining reality.

What is more, VR experiments where experienced operators (miners) take part are fundamental, once it allows to better adequate training programs for younger workers or trainees [13]. Lei et al. [12] developed a new system capable of surpassing one of the most significant handicaps of the already developed systems because most of the applied training tools in China are constructed to deal with just one of the disaster situations, lacking the desired training effect. The authors accomplished that by entering randomness to their simulation systems, which would require more reasoning and training from the users than the typical software. Additionally, the drill simulation created allows reducing the demand on human resources and equipment, and materials for emergency rescue drills, which could lead to a higher implementation in companies, in real working context. The experiments from Grabowski & Jankowski [13] had the same positive feedback and encouraged owners of training facilities to cooperate with the polish mines. Cai et al. [17] not only showed that the assistance of VR could be faced as a systematical methodology to provide risk simulation in coal mines, but also to help to understand the actual impact of those risk factors in emergencies. The authors' work culminated in a full-operational model for the risk behaviours in coal mines [14], where the training effect rose exponentially. Chen et al. [15] was the only author making use of VR as a teaching methodology in classroom. Its application leads to a higher interest in mining study, narrowing the gap between what is being taught and the actual mining practise, which, once more, shows that adequate training prevents failures that can be fatal in the real context.

On the other hand, in the construction sector, Building Information Modelling (BIM) is being used to integrate the multiple dimensions of a project. However, BIM, as a stand-alone tool, cannot acquire real-time data, identify hazardous zones and monitor construction sites. To overcome this issue, some technologies such as sensors and tracking devices are being developed onsite enabling the rise and development of virtual reality [18]. Cheng et al. [19] developed an algorithm to track the workers' movement and to identify the hazards along their paths. In another study from Teizer et al. [20], it was developed a real-time warning system that works on a Radio-Frequency Identification (RFID) technology, which sets of an alarm to warn the worker to a specific hazard. For training purposes, Teizer et al.

[21] integrated the warning system with a 3D virtual reality to assist workers in their day-to-day tasks. Summarising, this sector is making use of the available technologies, not only to meet their work agendas but also as a safety management tool, *in loco*.

5 Conclusions

The purpose of this review was to seek for evidence of the VR applications in the extractive industry, focusing on the safety management issue. Analysing the results, it was possible to verify that the mining sector is far from what has been achieved in the construction field, despite the fact that training is seen as a powerful tool to improve safety awareness. However, it is essential to keep in mind that no matter how many simulations the miners (students, trainees, or even operators) run and practise, it is impossible to predict with high accuracy how the miner would act in a real-life situation. In the near future, a statistical analysis of accidents in mines would enable a qualitative assessment of the VR training influence on the number of accidents at work.

The mining industry still has many gaps concerning the virtual reality application; in addition to being only focused in running training simulations, it still has not used these technologies on the field (in real ground context). What is more, the researchers are only focused in the coal mine industry, since it is the one where most accidents take place, however, other grounds of exploitation should not be forgotten, because their operators still lack safety awareness.

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Occupational Accidents in the Mining Industry—A Short Review

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Abstract The mining industry is one of the most challenging environments concerning safety issues. Although most of the hazards are well identified and studied, the impact of mining equipment on accidents is still not fully comprehended. PRISMA statement methodology was used in order to conduct proper research regarding this gap; from the 2594 identified papers, only 14 answered the main exclusion and inclusion criteria and were included in the study. The primary results show that haul truck, dumpers and conveyors are the equipment with higher impact on the accident rates and that proper training programs and other safety measures would help decrease the tendency.

Keywords Heavy machinery · Mining equipment · Safety at work

1 Introduction

The mining industry is a vital economic sector, comprising the utilisation of coal, metal, and non-metal minerals [1]. However, historically, mining has also been one of the most hazardous working environments in many countries around the world [1–3]. For instance, coal mining operations have the highest machine-related accident rates and the highest number of severe accidents, especially in underground operations [4].

According to the International Labour Organisation (ILO), information updated in 2018, the number of work-related accidents has increased, and more people are

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dying due to workplace injuries and illnesses every year. Usually, accidents are the result of unsafe acts committed by people and/or the existence of unsafe physical or mechanical conditions in the working place [3].

Regarding the increasing production demands, storage and use of hazardous substances, the accident has become a greater concern. Still, identifying and controlling the main cause can be the key to accident prevention [3]. Although exposure to noise (for, i.e.) is a significant occupational mining hazard, the mining conditions can have a more significant impact on the safety experience of mine workers [6]. High temperatures and inadequate illumination negatively affect workers' alertness, leading to reduced concentration levels, which, in its turn, increase workers' risk of occupational injuries. The lack of danger warning signs, abrupt slopes and slippery surfaces with no support to prevent falls, sharp edges with no guards to prevent cuts, are all factors which contribute to making the underground workplaces a risky working area [5]. As a matter of fact, the most frequent cause of fatal injuries is falls, which includes slipping and falling or being knocked off a piece of equipment and falling [7]. As a result, this industry continues to be associated with a high level of accidents, injuries, and illness [8]. Frequently, the poor technology used both in the extraction and recovery of minerals, along with the failure to invest in safe working equipment (including personal protective equipment) and tools threaten miners' lives as well [7]. Albeit this, equipment influence on accidents is poorly studied. However, it is known that the increase in the machine speed results in an increased chance of being struck by the equipment [9]. Risks associated with mining machinery are affected by four recognised major factors: mine design, machine specification, human factor and working environment [10]. This study was undertaken with the objective of more thoroughly characterise equipment-related mining accidents and its root causes, in order to provide further knowledge on this issue.

2 Materials and Methods

To conduct this short review, Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA Statement) [11] was used. The search included some of the central multidisciplinary databases and journals such as Academic Search Complete, Cambridge Journals Online, Current Contents, Emerald Insight, Scopus and Web of Science, as well as engineering databases and journals, Geological Society of America, IEEE Xplore, Inspec, SAGE Journals, Science Direct, Ingenta, Directory of Open Access Journals and Taylor and Francis. The search was conducted, whenever possible, in the title, abstract and keywords, using a keywords sentence to limit the study ("accident" OR "hazard") AND (mine OR quarry OR "open pit" OR "open cast") AND (equipment). As screening criteria were considered only articles and articles in press, published between January 2010 and April 2018, published in journals and written in English, analysing accidents occurring in the mining industry.

3 Results

From a total 2594 identified articles, 1470 papers were excluded by date. The second exclusion criteria applied was the type of paper: only experimental studies were considered, excluding 361. The paper source was also considered, leading 12 more articles out of the study. Papers not written in English were disregarded, leading to the rejection of 94. Duplicates (25 articles) and works without full-text access (after trying to reach the authors) (15 papers) were removed. After reading the title and the abstract, 573 articles were not in accordance with the proposed objective. After this process, 39 papers were considered eligible and were full-text screened, in order to determine evidence of mining equipment accidents. After analysing their references, another 4 papers were added to the research. After the selection process, 14 articles were included for a qualitative synthesis, Fig. 1. Data concerning the period range of the studies and analysed equipment is provided in Table 1.

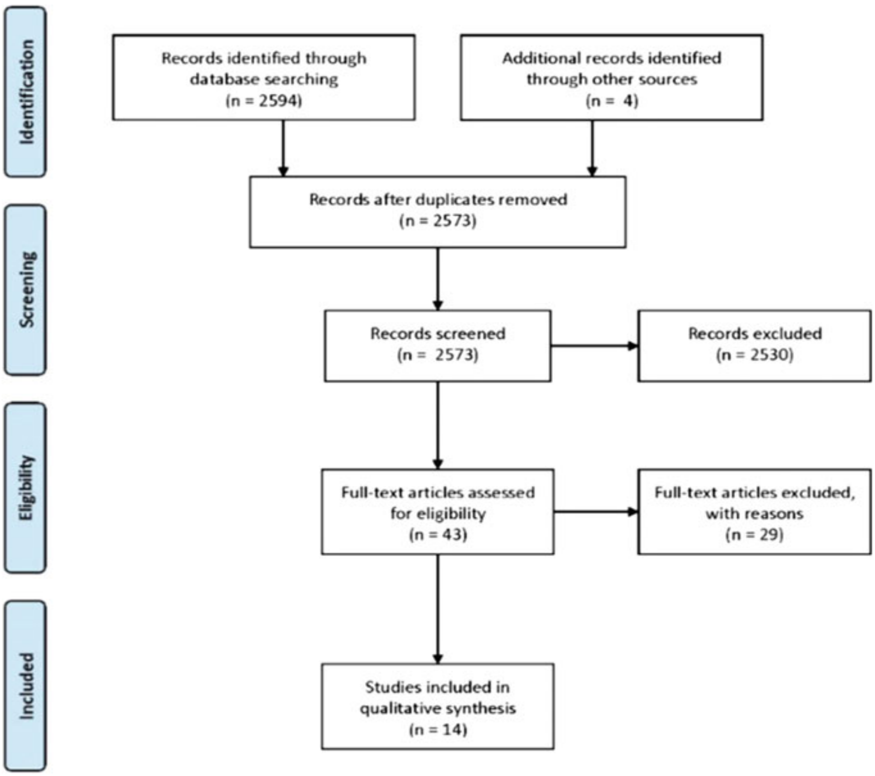

Fig. 1 Research PRISMA flow diagram

Table 1 Analysed equipment and time range per author

Author	Country	Time range	Equipment
Kecojevic and Radomsky [12]	USA	1995–2002	Loader, truck
Groves et al. [13]	USA	1995–2004	Haulage truck, front end loader, non-powered hand tools, conveyor, continuous miner
Kecojevic et al. [1]	USA	1995–2005	Haul truck, belt conveyor, front-end loaders and miscellaneous
Md-Nor et al. [14]	Canada	1995–2006	Loader, dozer
Permana [3]	Romania	2003–2010	Haul truck
Burgess-Limerick [15]	Australia	2006–2008	Continuous miner, bolting machine, LHD, longwall, transport, shuttle car, hand-held bolters, grader, stone dusting equipment, dolly car, road header, longwall move equipment, and gas drainage drilling equipment
Ruff et al. [4]	USA	2000–2007	Conveyor, bolting machine, milling machine, LHD, front-end loader, continuous miner, crane, crusher, shuttle car, forklift, truck, shovel, hand tools
Onder [8]	Turkey	1996–2009	NM
Kumar and Gosh [10]	India	1995–2008	Dumper, drilling machine, shovel, loader, dozer
Zhang et al. [16]	USA	1995–2011	Haul truck
Dash et al. [2]	India	1980–2013	Wheeled vehicles
Clark et al. [17]	USA	2003–2012	Jackleg drill
Dindarloo et al. [18]	USA	2000–2012	Off-road truck
Nasarwanji et al. [19]	USA	1996–2015	Front-end loader

*NM = Not Mentioned

Kecojevic and Radomsky [12] collected data provided by the Mine Safety and Health Administration (MSHA): 32 loader-related fatalities and 89 truck-related fatalities occurred during the analysed period (1995–2002). The highest proportion of fatality accidents with the loader (41%) happened when personnel got hit, struck or run over by the wheel loader, followed by equipment rollover from elevated edges (34%), repair or bucket replacement (13%) and the other 12% slopes, overburden, and so forth. Concerning trucks, incidents involving 'rollovers' (from elevated edges), waste dump or elevated haul roads were the most common, representing 47% of the total fatalities; the second highest proportion of incidents (28%) includes fatalities when mine and non-mine personnel were hit, struck or run over by the truck. The other accidents were direct collision between trucks and other vehicle (11%), equipment repair (8%), direct contact between the truck and high-voltage power lines (3%) and "others" (3%), including incidents such as a truck fire, a truck collision with the rock berm, among others.

Groves et al. [13] extracted data from the MSHA (1995–2004), where a total of 190,940 accidents, injuries, and illnesses were recorded. There were 775 fatalities reported, of which 597 (77%), as well as 160,627 incidents were associated with mining equipment. Off-road and underground (ore) haulage trucks account for the most significant portion of the fatalities (16%), followed by front-end loaders (9%), continuous miners (8%), conveyors (6%), (non-ore haulage) trucks (6%), and cranes/derricks (32, 5%). The remaining equipment accounted for less than 5% of the fatalities.

Kecojevic et al. [1] data were extracted from MSHA accident investigation reports (1995-2005): 483 fatalities were recorded in the studied period. The highest amount of fatalities was related to hauling trucks (22.3%), belt conveyors (9.3%), front-end loaders (8.5%), and miscellaneous equipment (36.6%). The remainder fatalities distribution ranges from 6.2% for continuous miners to less than 1% for hoisting. Workers with less than five years of relevant mining experience constitute 44% of all fatalities that occurred during the analysed period.

Md-Nor et al. [14] studied data from MSHA reports (1995–2006), where 43 fatalities using loaders were recorded for the studied period, also determining that 25 out of the 43 victims were not the equipment operators. Regarding the dozers, 30 fatalities occurred.

Permana [3] analysed data obtained from the Directorate Technique and Environment of Mineral and Coal reports. The mines' accident report showed an increase from 2003 up to 2010, with 200 fatalities. The authors emphasised a mine disaster occurred in 2009, where 44 miners died. In the study, a risk assessment was performed, and the source of mine accidents was found to be the tools, and mine accident locations were mechanic's workshop and mine pit.

Burgess-Limerick [15] analysed data from Coal Services Pty Ltd (2006–2008), where the number of injuries reported by underground was 4,633 (excluding injuries occurring on the surface at an underground mine, as well as hearing loss claims). The Mining equipment was "responsible" for 2149 accidents (46%) of the total accidents: continuous miner (12%), bolting machine (6%), LHD (8%), long-wall (7%), transport car (4%), shuttle car (3%). Other equipment involved in the remaining 308 injuries included hand-held bolters (115) and a variety of other equipment such as graders, stone dusting, dolly cars, road headers, long-wall move equipment, and gas drainage drilling equipment.

Ruff et al. [4], using the MSHA accident database (2000–2007), studied accidents that involved every mining equipment. The highest number of severe accidents involving machines occurred in coal mining (with 242 cases), followed by stone (136), sand and gravel (83), non-metal (53) and then metal mining (48). Regarding the equipment involved, conveyors (80 in 562 analysed accidents) in surface operations, roof bolting machines, haul trucks, and front-end loaders were most frequently involved in accidents. For mobile earth-moving machinery (trucks, loaders, scrapers and dozers) most of the severe accidents occurred during the operation of the equipment. Of the 562 accidents, 46% occurred during the operation of the machine, and 25% occurred during repair or maintenance actions.

Although Onder's [8] objective was to predict the probability of accidents with greater or less than three lost workdays, he studied the main accident and its causes in Western Lignite Corporation (GLI) of Turkish Coal Enterprises, between 1996 and 2009. The largest proportion of injury accidents resulted from mining machines (39.2%), and the other stated reasons were with general machinery (25%), manual and mechanical handling (16.7%), hand tools (11.9%), and struck by/falling object (7.2%). Maintenance personnel (79.4%) were more likely to be injured than workers (11.7%) and drivers (8.9%).

Kumar and Gosh [10] analysed data provided by Directorate-General of Mines Safety (DGMS) (1995-2008), finding out that dumpers caused the maximum percentage of fatal accidents (59%) and drilling machines caused the least (2%) among all equipment. The human fault (the one that takes place out of the vehicle system) is the highest responsible factor ranging from 50 to 80% of the total fatal accidents due to four machines (dumper, excavator, loader and dozer).

Zhang et al. [16] extracted data from MSHA (1995–2011). From the 137 total fatalities, 21.6% were haul truck related, where the surface coal presented the highest fatality percentage (56%). In their study they analysed 12 haul truck-related accidents (surface coal mining), in order to find its root cause; the two most common causes were inadequate or improper pre-operational check and reduced maintenance. Failure to wear a seat belt and inadequate training were also significant contributing factors in all accidents.

Dash et al. [2] analysed data from DGMS (1901–2010), which states that there were 1174 fatal accidents and 1319 fatalities in Indian coal mines, out of which 37.64% were fatal accidents, from which 34.57% of fatalities were due to the single cause of transportation equipment. Most of those accidents occurred in the dumpers.

Clark et al. [17] analysed reports from MSHA (2003–2012), where 483 accidents were recorded, of which 91% took place in metal mines, 6% in coal mines and 3% in non-metal mines. The primary sources of injury for jackleg drill operators reported were fall of the ground; machinery, including pinches and strains; and slips or falls.

Dindarloo et al. [18] focused their study on truck-related accidents, using data from MSHA (2000–2012). From the dataset, 50831 injuries (both severe and non-severe) and 125 severe records that affected 140 employees were identified. The "severe injuries" designation consisted of 88 fatalities and 52 permanent disabilities.

Nasarwanji et al. [19] studied accident data, from MSHA (1996–2015), although the authors disregarded fatal accidents. Of the 1457 incidents in the final dataset, 63.4% (924) occurred during egress, 25.2% (367) during ingress, 4.8% (70) during maintenance activities, and the remaining 6.6% (96) were either "unknown" event or during other tasks.

4 Discussion

In order to be efficient in production and meet mineral quotas, heavy machinery is necessary within the modern mining sector [6]. However, it poses one of the highest contributors to accidents in this industry, fact that every analysed study supported. Between working demands, work pace control and workload, operators lack the awareness and attentiveness to their own safety [6, 19]. Failure to wear seatbelts were also associated with several loader and truck accidents [1, 12]. Not following the safe working procedure or standard operating procedures, or even unsafe or careless actions also may be the cause of accidents [3, 18]. Failure to recognise adverse geological conditions, to respect the loader's working area, to maintain adequate berms, lack of warning signs and appropriate mine maps, inadequate provision for safety level and failure to adjust to poor weather conditions are all worker behaviours that pose a significant threat [12, 14]. Loss-of-control of the equipment was found to be the leading source of machine-related fatalities in surface mining [4]. Mechanical failures were also pointed out [12, 14, 18]. In Kecojevic and Radomsky [12], other causes were stressed, such as collision with pedestrians or with another vehicle, rollovers, contact with public utility lines and slope failure. Concerning overall mobile equipment, the operator's visibility continues to be a problem both for underground and surface mining operations [4]. The occupational group having the highest percentage of all accidents is maintenance [8, 14, 15, 18] and nearly half of the affected employees had less than five years of job experience [18]. The root causes being some part of the person getting caught between the moving parts of the equipment or handling a variety of equipment (bolting supplies, for example) [15]. Moreover, Groves et al. [13] showed that a significant portion (54%) of accidents were due to material handling, machinery (12%), hand tools (11%), roof fall (10%), and powered haulage (8%). Jackleg drills, from all the used drills, are the ones which have a higher rate of accidents, being the leading cause for small falls of ground [17]. However, most accidents happen while using transport equipment such as haul truck [1, 13, 16] and dumpers [2, 10] and mostly in coal mining [4, 16].

5 Conclusions

The articles' analysis showed that the types of activities most often associated with injury in mining had not changed much over the analysed period and, despite different realities (countries) were studied, the number of accidents was higher than it was expected. The equipment contributing the most to such issue are haul trucks, dumpers and conveyors, especially during maintenance actions.

Constant vigilance regarding the identification and control of mining hazards should be considered as an approach to accident prevention, as well as an effective monitoring and equipment operations control. Compliance with rules and regulations should be complemented with training and education, and special focus should be given to less experienced workers, who appear to be more vulnerable to equipment-related accidents. These educational programs should include ergonomic (hand) carrying, careful use of hand tools, and the importance of using personal protective equipment. Factors such as training and competence assurance management of fatigue-induced errors and control of workload could also eliminate some errors that, consequently, lead to accidents.

What is more, manufacturers should improve equipment safety and protective devices at some entry points, in order to prevent workers from being caught in or rolled up in machinery during operation. Careful job planning, and effective communication and information relating to tasks could avoid most accidents.

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Safety Stream Mapping—A New Tool Applied to the Textile Company as a Case Study

I. Gonçalves, J. C. Sá, G. Santos and M. Gonçalves

Abstract Nowadays, the competitiveness between organizations is a growing reality. The Lean philosophy has proven to help companies improve their productivity and reduce waste. The relationship between lean and safety, Lean Safety, is not clearly understood, which should not be the case, since these two concepts are compatible and both strive to improve processes. This paper presents a new methodology designated Safety Steam Mapping (SSM). The SSM is a methodology based on VSM (Value Stream Mapping) and WID (Waste Identification Diagram) that allows, through the observation of a color scheme, to perceive the areas/processes belonging to the productive flow of the organization, what is the associated risk and what is the cause of the lack of safety, thus facilitating the understanding of the company's risk assessment. The SSM was designed in order to assist any member of an organization, internal or external, to perceive the safety state of the organization. The main goal of this methodology is to provide all stakeholders a macro view and easy interpretation of the level of safety and risk level of the areas/processes of the company. A case study of a textile enterprise is presented, as well as, the respective results.

Keywords Lean safety · Value stream mapping · Lean tool · Safety stream mapping

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1 Introduction

In the present times, Lean philosophy is well known worldwide for bringing benefits to companies. There is many literatures describing its advantages and limitations, as well as, practical cases showing in what way applying Lean improves organizations, being a solution for their survival and success [1].

On the other hand, and not less important, occupational safety related questions are another topic that firms tend to consider each time more relevant.

The lack of safety in the workplaces is a way to generate waste, through accidents at work. It results in production stoppage and possible defects [2].

This work was created to serve as a way to merge safety and Lean philosophy through the development of a integration methodology based on Value Stream Mapping (VSM) but could also be made from Waste Identification Diagrams (WID). These two methodologies are characterized as being graphical representations of an organization process flow, which analyze benefits in waste identification. VSM is an important step in "Going Lean". Value flow maps allow to comprehend the current condition and project a future one. Even more important, it is the mapping that allows to prioritize where to focus improvement actions [3]. WID allows an immediate visual diagnostic of the sectors that show bigger wastes and that can be used as the first step to continuous improvement [4].

This new tool, entitled Safety Stream Mapping (SSM) aims to overview areas of the organization with most occupational risks in a simple and intuitive way. To validate this methodology, it is introduced a case study in a textile company in order to understand this methodology applicability.

2 Literature Review

2.1 Value Stream Mapping

VSM is a process mapping tool used to improve the understanding of the activities sequence and process information flow, to produce a product or a service. VSM's use as a waste detector tool and implementation support for the Lean philosophy has reached the most diverse sector and contributed to removing some old concepts [5]. VSM use helps identifying the waste source, provides a common language for its analysis and makes material flow connections easy. It is also an effective way of recording lead times, setup times, distances, Overall Equipment Effectiveness (OEE) and other indicators so that the responsible can clearly visualize process performance [6].

Most of the processes demand focus in safety related questions, since they may have occupational risks that can be labeled as waste source, and this way traditional VSM could be more informative regarding that aspect, including safety questions [7].

Jarebrant et al. [8], presented a VSM inspired methodology entitled ErgoVSM. It was developed to also consider the worker's physical exposition. ErgoVSM includes intervention proposals highlighting, besides waste reduction, ergonomics, being a viable tool to be used by production engineers, since includes ergonomically considerations, thus improving, workers' health and safety in their work stations [8].

2.2 Lean Safety

Safety management aims to ensure "zero occupational accidents" and "zero occupational diseases", which requires proactive processes. Safety management can perfectly match with Lean concepts, because Lean believes that there must be a "deliberate way" to follow for continuous improvement. Lean strategies encourage less material in the workplace, an orderly and clean workplace, and a systematic workflow. Therefore, standardization, systematization and regularization of production can be expected to lead to improved safety conditions [9].

The loss of capacity or injury by workers and the consequent cessation of the productive process represent waste. Lean aims to minimize wastes and continuous improvement, so the relationship between Lean and safety is clear [10].

All significant changes are driven by different thoughts, in other words, lean thinking. As the basics become better known and understood, and sometimes become part of the corporate culture, they can be used more effectively to improve safety at a strategic level [11, 16].

Organizations begin to realize that top management should improve safety performance by involving workers to make the company culture excellent. Safety and lean can form an alliance to reduce the greatest possible waste: accidental injuries in the workplace [12], often with serious consequences.

Watson [17] has created a safety management system that integrates the Lean philosophy, which can be simplified as "ECTR" (Eliminate, Control, Train, Require). The first step requires identifying and eliminating hazards. Eliminating the safety difficulties usually allows you to eliminate steps 2, 3 and 4. Step 2 is necessary when hazards cannot be eliminated and must be controlled. Steps 3 and 4 are required when hazards are controlled. Employees should be aware of hazards and trained on safety procedures [13]. On the other hand, Song et al. [14] carried out a study whose main objective was to apply Lean concepts and tools for the management of safety in oilfields [14]. The authors created a safety management method, which they called a "DREAM" method (Define, Recognize, Evaluate, Apply, Monitor). Each of the steps has its purpose and is supported by Lean concepts and tools.

2.3 Safety Stream Mapping

This work intends to demonstrate that Lean philosophy has impact in safety questions, such as, Lean Safety, through the development of a generalized methodology—that allows that any organization can adapt to their business—obtaining visible results regarding safety.

This methodology's focus help management finding the biggest occupational risks and to be used as a first step for a future roadmap to improve occupational safety, that can be used in any organization.

This new tool pretends to conceive an organization process flow, such as VSM. The objective of t is to recognize easily those sectors where are major safety failure by identifying each level of risk.

3 Methodology

In legal terms, all companies are required to make a risk assessment and keep it up to date. This new methodology arises from the need to easily communicate the level of risk of each step of the process. This is the premise for SSM application. Thus, the objective of the SSM is not to do a risk assessment but to use the valuations made by the companies through various methodologies such as BS 8800 and others. In a simple way it is intended to convert the high number of risk assessment records into a simple image, with information for all.

As VSM, it is necessary to understand what processes are part of the organization productive flow. Each process is represented by a cube. Every process occupational risk level is hierarchically arranged in 4 levels, very serious, serious, satisfactory and controlled, each identified by different colors as it can be seen in Table 1.

Processes risk level is determined considering each process occupational risk evaluation. For each process is realized the identification of all existing dangers, what risks are associated, as well as preventives measures, in a way to understand what's the risk level that each sector presents. There are various risk assessment

Table 1 Levels of occupational risks

Level	Color	Meaning
Very serious		Immediate intervention
Serious		Correction
Satisfactory		Improve
Controlled		Maintain situation

methodologies, but in this case study it was used the Probability and Consequence methodology [15].

The cause of lack of safety is divided into three groups: lack of human safety—safety flaws due to human errors; space related safety flaws caused by unstable and unorganized environment; and lack of safety regarding equipment provoked by maintenance flaws, excessive use and lack of planning. For this step's success it is necessary the most complete knowledge of the executed work and where can the risks associated to the execution be found, with workers and manager's contribution in such a way to be possible to arrive at a conclusion. It is important to notice that the cause's classification has the prevention measures in consideration, associated to each task's risk and can be classified as risk associated with human failure (HMN), risk associated with the workspace safety failure (SPC) and risk associated with equipment (EQ) [18]. For a better understanding of cause's classification, Table 2 provides an example.

As a way to resume the mandatory steps for an organization SSM creation, it is required to follow these steps:

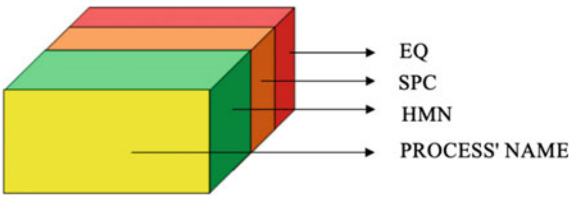
1. Identification of the organization productive flow processes;
2. Analyze existing risk evaluation present in the organization in each process/sector;
3. Assign lack of safety responsibility to each existing danger (HMN, SPC, EQ), having in mind existing preventive measures.
4. Count dangers by process and in each process count the dangers caused by lack of safety (HMN, SPC, EQ)
5. Calculate risk level (RL) average for each process/sector.
6. Regarding each process, calculate the average cause-related RL.
7. Assign each process a color, accordingly to the RL.
8. Assign each cause a color, inside each process, accordingly to the obtained RL.

SSM graphical representation is made through cubes, representing each process. Each cube is divided in three parts, each part representing lack of safety causes, its dimension depends on the among of dangers associated to each cause and the color depends on the obtained risk level. Figure 1 represents the cube for a better understanding.

Table 2 Explanatory table of classification of lack of safety

Danger	Risk	Consequence	Preventive measure	Cause
Using the guillotine	Guillotine blade contact with the hands	Amputation of hands	Placement of bimanual commands	EQ

Fig. 1 Cube representation



4 Results—Case Study

The case study shows the application of SSM in real context in a Portuguese textile company. The productive process consists of 9 steps. For a better perception of the productive process of the company, Fig. 2 presents the VSM.

For SSM execution, the eight steps presented in Chap. 3 were followed, being these necessary for SSM's making. The company's existing risk evaluation was used, having been defined each process preventive measures related causes of each danger.

In the company's SSM are represented 9 cubes. The cubes are sorted and represent the processes that are part of the organization process flow, as represented in the company's VSM. In the lower part of each cube, in the informative boxes, it's possible to see the number of workers, by shift, of each process, the sector risk level and cube's 3 parts, cause representative of the lack of safety. The cube's elements colors come from the risk level obtained through the company's risk assessment. Risk evaluation method used by the organization is the Probability and Consequence method and Table 3 represents its classification by colors, taking into account the risk level [15].

The arrows connecting the processes show the risk level attached to the transport and are equally painted based on its value. Figure 3 shows the graphical representation of the company's SSM.

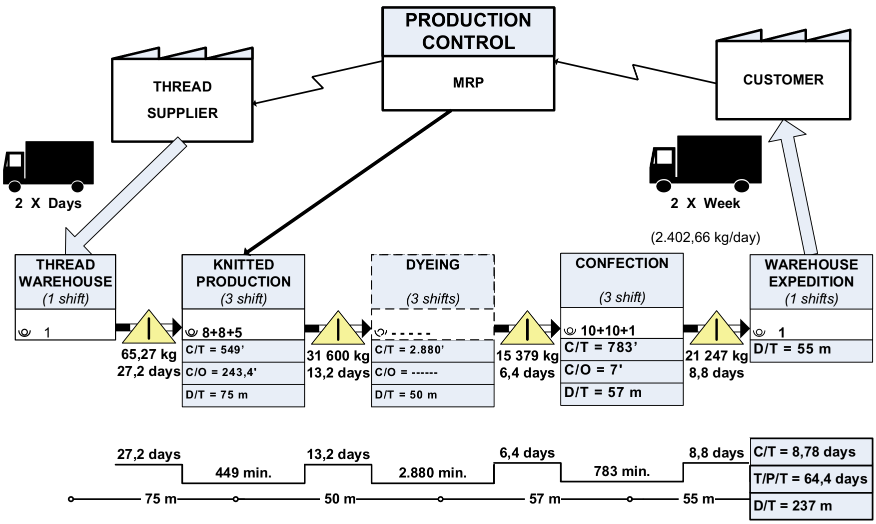


Fig. 2 Company's VSM

Table 3 Probability and consequence method [15]

Intervention level	Risk level	Colour
I	4000–600	
II	500–150	
III	120–40	
IV	20	

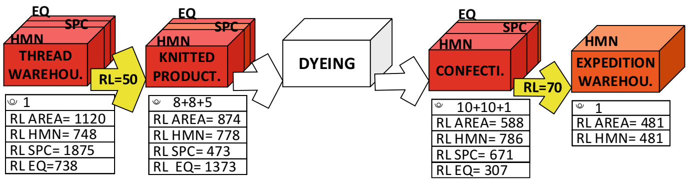


Fig. 3 Company's SSM

5 Discussion

SSM can be considered as a complement to the company's VSM, presenting relevant information regarding safety questions, such as each process risk level, risk level related to the lack of safety caused by process and transportation between processes risk level. In an overview it is possible to withdraw some conclusions about SSM's application in a textile sector company. The dyeing cube and its transportation are not painted due to being external activities, outsourced by the company. Overviewing, regarding the organization risk evaluation, and having in mind its colored representation, it can be concluded that the company presents a high level risk related to each sector/process, namely because most of the processes are painted red and orange, corresponding to intervention level I and II, respectively, being very serious and serious risks.

Mostly, lack of safety is caused by human flaws, followed by space and at last due to the equipment failures. It's worth noting the expedition warehouse, once that 100% of the lack of safety is caused by human failures. Transportation show a satisfactory level, intervention level III, being possible to improve.

6 Conclusion

This work addresses two themes present in any production unit, which must be taken into account for the growth and sustainability of an organization. The Lean philosophy, which seeks to reduce costs and increase turnover through the elimination of waste and non-value-added activities, and the concept of safety, whose relevance in its development should be seen as an investment and not as a loss of time, since lack of safety causes waste, which does not bring any kind of advantage to an organization This new methodology was designed in order to assist any member of an organization, internal or external, to perceive the safety state of the organization. By observing this methodology, it's possible to perceive all of the processes that are part of the productive flow of the organization, the level of risk associated to each one of them and what are the main causes of the lack of security achieved through the risk assessment of the organization, something that is legally required. The creation of this methodology allows any organization to perceive its level of occupational risk through the observation of a color scheme that portrays the level of safety of the organization, which is very useful. As suggestions for future work, it's considered important to implement it in other sectors of activity and a study on Lean tools that can be useful on improving the lack of safety observed through the SSM.

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Analyzing and Classifying Risks: A Case-Study in the Furniture Industry

Celina P. Leão, Matilde A. Rodrigues and Irene Brito

Abstract In this work we propose a methodology which permits the risk analysis and classification of occupational accidents in industrial settings. Data used in this study corresponds to accidents that occurred in the furniture industry in Portugal in 2010. A loss random variable is constructed in order to model the number of lost days implied by different contact modes of injuries in industry. The corresponding risk measures, such as Value-at-Risk, expected loss, loss variance and exceedance probabilities are determined in order to analyze and classify the contact modes according to their risk level, allowing the identification of the most problematic and the less problematic accident category in this industry. Contact with cutting, sharp, rough material was the most problematic whereas contact with electrical current, temperature, hazardous substance was the one with lower risk level.

Keywords Risk analysis · Risk classification · Value-at-Risk · Industry

1 Introduction

Furniture industry is one of the most important sectors of activity in Portugal, in particular in north and center of the country, underpin a significant part of this region economy [1]. This sector is dominated by small and medium-sized

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enterprises (SMEs) [2]. Like other SMEs, also furniture industry face several challenges, such as competition, turnover, ageing workforce or limited resources (human, financial and technological) [3–7]. These companies have also more difficulties with risk assessment process [1, 5]; as a consequence, poor work conditions are expected.

Rodrigues et al. [1] in a study involving 14 small and medium-sized Portuguese furniture industries, found that these enterprises face several problems related to the use of unsafe machines, unsafe behavior and manual work.

Considering this scenario, it is not surprising the high number of occupational accidents in furniture industries [1]. Understanding the key scenarios related to occupational accidents in the furniture sector, as the probability of resulting in some damages to workers (consequences), appears of paramount importance in order to identify critical areas of intervention and help both authorities and enterprises to support decision-making and define an effective risk management strategy.

To this end, risk analysis can provide important information about accident events in furniture industry. Risk analysis is a process that involves developing an understanding of the risk, providing an input to decision making process (ISO 31000:2009). However, because SMEs lack sufficient accident information at the company level, several researchers recommend the use public statistics to support decision-making process about the risks related to occupational accidents (see e.g. Rodrigues et al. [8], Carrillo-Castrillo et al. [9], Jacinto and Silva [10]).

The Value-at-Risk (VaR) is a risk measurement tool frequently used in the field of financial management and actuarial risk theory. VaR refers to a loss level that will not be exceeded for a certain confidence level, during a certain period of time [11]. However, it can bring important inputs also for the risk of occupational accidents. In fact, VaR was already previously used to describe accident risks in different sectors and activities, such as accidents in energy sector [11] or highway hazmat shipments [12]. In the present study, VaR principles are adopted to identify the most important accident scenarios in the furniture industries.

In the methodology that we are proposing, a loss variable is defined in order to model the number of lost work days, depending on the accidents' occurrence probability and estimated number of lost days. Furthermore, expected loss, variance of loss and the Central Limit Theorem are used in the risk analysis and classification.

2 Risk Analysis

We consider six contact modes of injury categories, denoted by $i = 1, \ldots, 6$, which occurred in the furniture industry in Portugal in 2010 (see Table 1).

Let n be the total number of accidents and n_i be the number of accidents of category i for $i = 1, \ldots, 6$. Note that $n = n_1 + \cdots + n_6$. Let b_{T_i}, $i = 1, \ldots, 6$, denote the total number of lost days due to accidents of category i.

Table 1 Contact mode of injury categories

i	Injury category
1	Contact with electrical voltage, temperatures, hazardous substances
2	Horizontal or vertical impact with or against a stationary object (the victim is in motion)
3	Struck by object in motion collision
4	Contact with cutting, sharp, rough material
5	Entrapment, crouching, among others
6	Physical constriction of the body, psychic embarrassment

We define the following variables:

$$b_i = \frac{b_{T_i}}{n_i} \tag{1}$$

represents the estimated number of lost days due to an accident of category i and

$$p_i = \frac{n_i}{n} \tag{2}$$

the occurrence probability of an accident of category i, where $i = 1, \ldots, 6$.

Considering the observed values according to the dataset of the 2010 work accidents in the furniture industrial sector, provided by the Portuguese Office of Strategy and Planning (GEP), we obtain the following results listed in Table 2.

One can observe that the accident category 4 has the highest occurrence. Considering the estimated number of lost days, it is accident category 5 which implies a higher number of lost days, however its occurrence probability is low, $p_5 = 0.08$, when e.g. compared with $p_4 = 0.33$.

In order to analyze the risks—lost days implied by each accident category—one must take into account the occurrence probability and the estimated number of lost days of each accident category. Therefore, we define the following loss random variable

$$X_i = I_i b_i, \tag{3}$$

representing the lost days associated to an accident of category i, where I_i is a Bernoulli (p_i) distributed indicator random variable, with p_i defined in (2), and b_i is

Table 2 Summary of results for each contact mode of injury

i	n_i	b_{T_i}	b_i	p_i
1	97	1135	11.70	0.02
2	523	17,457	33.38	0.12
3	958	18,082	18.87	0.22
4	1406	53,661	38.17	0.33
5	331	13,594	41.07	0.08
6	998	27,062	27.12	0.23

defined in (1). The expected loss and variance of the loss associated to an accident of category i are calculated as follows

$$E[X_i] = b_i E[I_i] = b_i p_i, \tag{4}$$

$$Var[X_i] = b_i^2 Var[I_i] = b_i^2 p_i(1 - p_i). \tag{5}$$

In order to classify the risks, we will also determine the probability of the loss random variable exceeding 7 days (one week) and 15 days (half a month) using the Central Limit Theorem:

$$P(X_i > \alpha) \approx 1 - \Phi\left(\frac{\alpha - E[X_i]}{\sqrt{Var[X_i]}}\right), \tag{6}$$

where $\alpha = 7$ and $\alpha = 15$.

The Value-at-Risk (VaR) is a standard risk measure in actuarial risk theory used to evaluate the exposure to risk (see e.g. Klugman et al. [13]). Since in the present context the loss is associated with an amount of capital, the VaR is useful to predict the amount needed for each risk that exceeds the lost amount with a high degree of certainty. The VaR of a loss random variable X at the 100p% level, denoted $Var_p(X)$ is the 100p percentile (or quantile) of the distribution of X. We write $Var_p(X_i)$ as the value of π_p satisfying

$$P(X_i < \pi_p) = p. \tag{7}$$

In the present case we will determine the 95% quantile, setting $p = 0.95$ in (7). Calculating (4), (5), (6) and (7) for the loss corresponding to the six contact modes of injury categories, we obtain the results listed in Table 3.

3 Analysis and Interpretation of Results

From the results summarized in Table 3, several findings emerge and will be presented below.

Table 3 Expected loss, variance, probabilities and VaR for each injury category

i	$E[X_i]$	$Var[X_i]$	$P(X_i > 7)$	$P(X_i > 15)$	$\pi_{0.95}$
1	0.26	3.01	0.00	0.00	3.12
2	4.05	118.72	0.39	0.16	21.97
3	4.19	61.55	0.36	0.08	17.10
4	12.44	320.05	0.62	0.44	41.87
5	3.15	119.51	0.36	0.14	21.14
6	6.27	130.77	0.47	0.22	25.09

The accident category which has the highest expected loss is accident category 4 with 12.44 days, whereas accident category 1 has the lowest expected loss: 0.26 days.

Accident category 4 has a considerable probability of exceeding 15 lost days: $P(X_4 > 15) = 0.44$. For accident category 6 the corresponding probability is half of this value: $P(X_6 > 15) = 0.22$, and for accident categories 1 and 3 it is approximately null.

Considering a loss of more than 7 days, the highest probability is attained again with accident category 4, namely $P(X_4 > 7) = 0.62$, followed by accident category 6, for which $P(X_6 > 7) = 0.47$. For accident category 1, we can say that this probability is approximately null. For the contact mode of injury category 2 and 3 considering a loss of more than 7 days is approximately the same $(P(X_2 > 7) = 0.39 \simeq P(X_3 > 7) = 0.36)$, but this reduce by half when considering a loss of more than 15 days $(P(X_2 > 15) = 0.16$ and $P(X_3 > 15) = 0.08)$.

The Values-at-Risk, $\pi_{0.95}$, in the last column of Table 3, can be interpreted as follows. For accident category 4, since $\pi_{0.95} = 41.87$, there is a 95% of certainty, that the number of lost days will be less than 41.87 days, or in other words, there is a 5% chance of exceeding this number of lost days. Accident category 1 has the lowest VaR, $\pi_{0.95} = 3.12$. This means that the risk of exceeding 3.12 lost days with accident category 1 is 5%, or, with a probability of 0.95 the number of lost days will be less than 3.12.

Note that accident category 4 has the highest variance, $Var[X_4] = 320.05$, thus this also indicates that this category of accident is riskier in the sense that it can lead to extremer values of lost days, i.e. to numbers of lost days which are very higher than the expected number of lost days.

Taking into account the previous results and analysis, we can classify the accident categories and order them according to their risk level. From the results given in Table 3, we obtain the ordering in Table 4, where the categories are ordered from the left to the right, from the highest to the lowest risk level.

We conclude that contact mode of injury 4 (contact with cutting, sharp, rough material) is the most problematic one for the industry, followed by contact mode of injury 6 (physical constriction of the body, psychic embarrassment), whereas contact mode of injury 1 (contact with electrical current, temperature, hazardous substance) is the one with lower risk level. As for injury categories 2 (crushing in vertical/horizontal movement on/against an immovable object (moving victim)), 3 (blow by moving object, collision) and 5 (entrapment, crouching, among others), which have an intermediate risk level, we can say that in terms of expected number

Table 4 Ordered injury categories

$E[X_i]$	4	6	3	2	5	1
$Var[X_i]$	4	6	5	2	3	1
$P(X_i > 7)$	4	6	2	3(5)	5(3)	1
$P(X_i > 15)$	4	6	5	2	3	1
$\pi_{0.95}$	4	6	2	5	3	1

of lost days, contact mode of injury 3 leads to a higher number of lost days, followed by categories 2 and 5.

However, considering the variance and the probability of exceeding more than 15 lost days, the results indicate that contact mode of injury 5 is more problematic, followed by injury categories 2 and 3. The probability of exceeding more than 7 days is higher for category 2; for categories 3 and 5 this probability is equal. Finally, taking into account the VaR, contact mode of injury 2 is riskier than 5 and both are riskier than contact mode of injury 3.

4 Conclusions

In this work a methodology which permits the risk analysis and classification of occupational accidents in industrial settings is proposed. The Portuguese furniture industry accounts for a significant part of the economy, however, the figures for accidents at work remain high. It is therefore important to analyze accident data for future measures to prevent accidents.

A loss random variable is constructed in order to model the number of lost days implied by different contact modes of injuries obtained in this industry. The corresponding risk measures, such as VaR, expected loss, loss variance and exceedance probabilities are determined in order to analyze and classify the contact modes according to their risk level.

Our contribution lies in identification of the most problematic and, at the other end, the less problematic, accident category in this industry.

In accordance with the risk measures considered different results were obtained. Contact with cutting, sharp, rough material (contact mode of injury 4) is the most problematic contact mode injury obtained for the furniture industry. On the other hand, with lower risk level the contact with electrical current, temperature, hazardous substance (contact mode of injury 1). Considering the contact modes with intermediate risk level and the probability of exceeding more than 15 lost days, the results indicate that entrapment, crouching, among others (contact mode of injury 5) is the more problematic, and based on the VaR, horizontal or vertical impact with or against a stationary object (contact mode of injury 2) is the most risky contact mode of injury.

Future work will be aimed at addressing the same methodology with more current data and to analyze the development of the incidence of accidents.

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How to Prevent the Risk of Slipping in Kitchens?—A Short Review

R. P. Martins, J. Duarte and A. Torres Marques

Abstract Kitchen workers are more prone to be injured due to slips and falls, being the floor surface contamination often the cause of slip accidents. The aim of the present study is the identification of the most efficient solutions to prevent the risk of slipping in kitchens. According to PRISMA statement guidelines, a short review was performed on 15 databases with 28 combinations of keywords. A total of 10 studies were considered eligible and were included in this study. The use of objective and subjective measures to assess floor slipperiness can help to identify and to evaluate workplace slip and fall hazards. Slipperiness causes and workers' perception should be taken into consideration to identify slipping hazards and develop different solutions based on the various functional areas. The establishment of measures to better control floor surface contamination, the reduction in transient exposures such as rushing, distraction and walking on a contaminated floor, the use of slip-resistant shoes and the identification of floor cleaning procedure may reduce the incidence of slipping and the risk of slipping in kitchens.

Keywords Risk of slipping · Kitchen · Coefficient of friction · Slipperiness measurement

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1 Introduction

Work-related slipping, tripping and falling on the same level present a significant safety problem and a meaningful source of occupational injuries with economic consequences reported worldwide [1–3]. It is important to study floor slipperiness in workplaces, in order to prevent the risk factors of slips and falls [3, 4].

The work pace in working environments such as foodservice and kitchens can sometimes be intense. Floor surface contamination with substances such as water, oil, grease, is often a cause of slip accidents and kitchen workers are more prone to be injured through this type of risk [5, 6]. The abrupt changes in friction across floor surfaces may result in a slip and probably a fall since it is not possible to make body posture adjustments when one unexpectedly encounters a low friction area. To assess floor slipperiness, different types of measures can be performed, being objective measures one of them. The potential risk of slips is usually indicated by the levels of coefficient of friction (COF), which measures the degree of friction between the shoe and the floor surface [7–9]. Slipping incidents are more likely to occur on floors with a lower COF. Floor slipperiness can also be evaluated using subjective measures. The perception about floor slipperiness is crucial in slip preventions, since the person may adequate gait patterns while walking on a slippery surface, reducing the probability of a slip [2, 10, 11]. Therefore, the purpose of the present study is to identify the most efficient solutions to prevent the risk of slipping in kitchens.

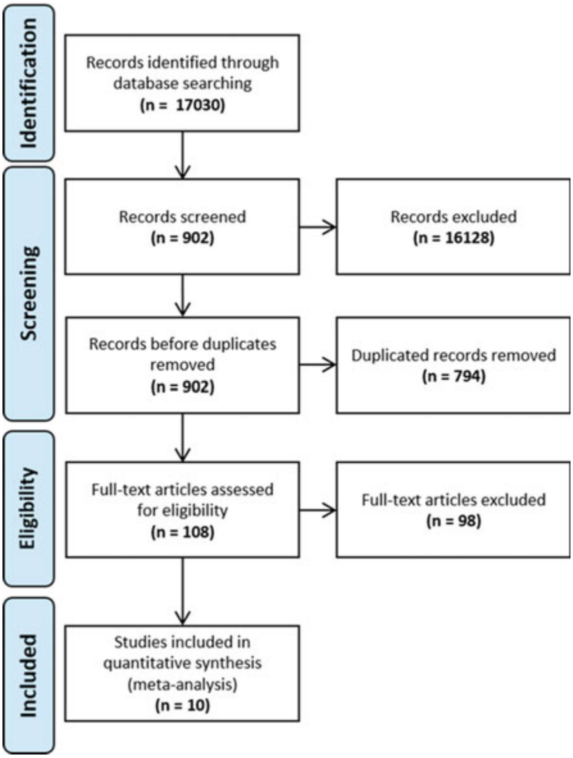
2 Methodology

A short review was performed according to the PRISMA statement principles [12].

Publications were searched between January 2000 and June 2017, on 15 databases including Scopus, Web of Science, PubMed, Academic Search Complete, ScienceDirect, Zentralblatt MATH, Beilstein via SCIRUS (ChemWeb), MEDLINE (EBSCO), SourceOECD, TRIS Online, ERIC, Current Contents, AGRICOLA Articles, PsycArticles, INSPEC. In the research were used 28 combinations of the following keywords: “kitchen”; “slip resistance”; “anti-slip”; “slipperiness”; “coefficient of friction”; “slippery”; “COF”; “slip”; “indoor”; “restaurant”; “foodservice”. The selection details of all relevant articles are shown in Fig. 1.

A total of 17,030 studies were identified at the beginning of the research. The titles and abstracts of the collected studies were screened, and the following exclusion criteria were applied: (1) date—excluded all studies prior to 2000 (5.213 studies); (2) type of publication—excluded those studies that were not articles, or articles in press (4.481 studies); (3) language of publication—excluded studies written in other languages than English (69 studies); (4) type of source—excluded studies which source was not Journals (841 studies); (5) excluded studies which title and abstracts appeared to be non-relevant to the study thematic (5.524 studies).

Fig. 1 Review stages



After the application of exclusion criteria, a total of 902 studies were obtained. The duplicated studies were also removed (794 studies) resulting in a total of 108 full-text articles. To be considered eligible, the study had to acknowledge the occurrence of slips, measure the slipperiness in kitchens and suggested measures to prevent the risk of slipping. A total of ten studies were considered eligible and were included in this study. The studies with information related to catering, food processing industry and waitressing were considered not relevant.

3 Results and Discussion

From the ten included studies, four were conducted in limited-service restaurants [13–16], four were conducted in fast-food restaurants [17–20], one study was performed in schools and in business foodservice operations [21] and one study was conducted in a student cafeteria [22]. Table 1 summarizes the studies' characteristics and the main extracted data per article, which included floor slipperiness measurement, COF values and the correlation coefficient between the averaged COF values and subjective ratings. The sample size of all studied papers, varied

Table 1 Studies' characteristics and main extracted data

Authors	Slipperiness measurement	COF	Correlation coefficient
Chang et al. [17]	Friction measurements Survey of floor slipperiness	Beverage (0.91) Oven (0.72) Walk through (0.90) Front counter (0.90) Fryer (0.79) Back vat (0.71) Sink (0.28)	Pearson's correlation coefficient 0.49 (p < 0.0001); Spearman's correlation coefficient 0.45 (p < 0.0001)
Courtney et al. [18]	Friction measurements Survey of floor slipperiness	Global mean COF (0.64)	Spearman's correlation coefficient −0.33 (p < 0.001)
Chang et al. [19]	Friction measurements Survey of floor slipperiness	Grill (0.69) Walk through (0.73) Front counter (0.77) Fryer (0.73) Back vat (0.69) Sink (0.28)	Pearson's correlation coefficient 0.33 (p = 0.01); Spearman's correlation coefficient 0.36 (p = 0.005)
Chang et al. [20]	Friction measurement	Grill (0.69) Walk through (0.74) Front counter (0.77) Fryer (0.72) Back vat (0.69) Sink (0.25)	N/A
Verma et al. [13]	Retrospective slipping survey Prospective slipping survey	N/A	N/A
Verma et al. [14]	Baseline survey and 12 weeks follow-up	N/A	N/A
Chang et al. [21]	Questionnaires	N/A	N/A
Yu and Li [22]	Friction measurements Employee survey	Fryer areas (0.17 and 0.21) Sink (0.17)	Spearman's correlation coefficient 0.87 (p < 0.0001)
Courtney et al. [15]	Friction measurements Baseline survey 12 weeks follow-up	Mean COF value not specified	(r = −0.16, p < 0.01)
Verma et al. [16]	Baseline survey 12 weeks follow-up	N/A	N/A

N/A Not applicable

from 45 to 475 workers. Workers from the study [17] were the youngest among all studies (22.5 ± 5.9 years) and the workers from the study [22] worked more hours per week (60.11 ± 7.10 h/week). Body mass index (BMI) was also measured in some studies [13, 15, 16] where almost half of the workers were considered overweight (BMI between 25.0 and 34.9).

As previously stated, floor slipperiness can be assessed through objective (specific friction testing) and subjective measures (worker's perception). The ten selected studies can be divided into two groups regarding this parameter: five referred that floor slipperiness was assessed through both objective and subjective measures [15, 17–19, 22], four studies referred that had used subjective measures [13, 14, 16, 21], and one study used objective measures only [20]. The studies from group one applied a survey about floor slipperiness and used the same equipment (slipmeter), Brungraber Mark II (BM II) following the guidelines published by the American Society for Testing and Materials [23]. According to COF values from the different kitchen areas, the sink was considered the most slippery area and the front counter the least slippery. In study [17] the employee's perception of the floor slipperiness was assessed using a four-point rating scale, with one as "extremely slippery" to four as "not slippery at all". The study showed that the levels of friction in different areas in the kitchens were significantly different. Grease, oil, and water were found to be the most present contaminants.

A similar floor slipperiness measurement protocol was later used by other authors [18, 19]. Cultural differences, the amount of water on the floors in the sink areas and greater use of slip-resistant shoes might have contributed to the lower correlation coefficients verified [19]. Study [22] was based in previous studies [17, 19], and presented a higher correlation coefficient. The floor friction levels were significantly different in each kitchen area. Numerous factors were shown to influence the sensitivity of perception to COF values: cultural beliefs, job practices, worked hours per week and the performed tasks in a cafeteria. It was also noted that the correlation results could have been different if more working areas were included. It was also verified that COF values in two studies were negatively correlated with worker's perception of slipperiness [15, 18]. Other factors rather than friction, were associated with workers' ratings of slipperiness, which may contribute to the difference in the degree of association between objective and subjective measures in the laboratory and in the field [18]. These included contamination of the footwear (foodstuffs and sauces), age of workers, and a prior history of slipping, falling or both. Safety professionals, risk managers and employers used workers' perception of slipperiness to identify slipping hazards and to assess intervention effectiveness [15]. The use of a slip-resistant mat covering the whole area, together with the replacement of the floor tiles over the working space could help increase friction in a working area [21].

Regarding the subjective measures, studies used a retrospective and prospective slipping survey [13], a baseline survey with 12 weeks follow-up [14, 16] and through the application of questionnaires [21]. It was found that cleaning workers used an enzyme-based floor cleaner together with hot/warm water, although this was not the protocol indicated by the manufacturer [13]. The adopted procedure could inactivate the enzymes and reduce the efficiency of the cleaner. As mentioned in prior studies, the floor cleaning procedure should identify the cleaning method, concentration, and type of floor cleaner, and temperature of the wash water [24].

An increased rate of slipping due to rushing, distraction and walking on a contaminated floor was also found in a crossover study [14]. Workers should, therefore, use slip-resistant shoes and increase their alertness state in the workplace, reducing these transient exposures. In active work environments, such as those found at limited-service restaurants, slip-resistant shoes worn for less than six months were moderately more effective than slip-resistant shoes used for more than six months [16]. The duration of usage impacts the slip-resistance properties of slip-resistant shoes.

In order to compare the work safety and work environment of foodservice between wet and dry kitchen systems, a set of questionnaires were applied to workers [21]. The study showed that dry kitchen workers suffered less from work-related diseases than those in wet kitchens. It was also found that the dry kitchen system was more efficient for food and work safety because of its superior design, with better partitioned functional areas than those in wet kitchens.

In accordance with the analysed studies, the combination of both objective and subjective measures can help to identify and to evaluate workplace slip and fall hazards. COF measurement and human-centred subjective assessment approach have their strengths and limitations. The COF method is generally more precise and less susceptible to individual biases. However, friction values could be vulnerable to device-dependent measurement error, floor conditions at the time of measurement and do not consider the frequency and variability of contamination. Cross-contamination can affect the readings of the COF on the BM II when using only one Neolite footwear pad in friction measurements. Friction measurement results may also reveal the friction status only at the time of measurement. Test conditions and the slider conditioning procedure should be carefully prepared. Also, the results of the perception survey reflected the floor slipperiness throughout the whole evaluated period [17, 19, 22]. Individual's perceptions of slipperiness are shaped by experiences over time and may be particularly valuable in occupational settings where workers have a comparatively long and recurring experience of working and walking in an area. Several variables were derived from self-reports of the participants, which may not have been able to accurately recall their slip and fall experience, which could result in the underreporting of these events [18]. Workers ratings could have been artificially constrained due to the use of a 4-point scale [15, 17–19, 22]. Another potential limitation is the co-occurrence of the transient risk factors during the control time and at the time of slipping [14]. It is difficult to evaluate the interaction effects of simultaneous transient risk factors (for example, a participant may be rushing, distracted and walking on a contaminated floor when the slip occurred). Not being able to control what type of shoes workers used could induce variations in perception and affect the correlation between perception and friction [17–20].

4 Conclusions

Foodservice managers, safety professionals, and employers should take into consideration both slipperiness causes and workers perception of slipperiness as an approach to identify areas with high slipping hazards and to assess intervention effectiveness. Several factors can affect the sensitivity of perception to COF values such as job practices, number of worked hours per week, the presence of contaminants, workers age, and a prior history of slipping and falling.

Some of the solutions to prevent slip and fall hazards in kitchens may include: identification and elimination of all contaminants sources on the floor to control floor surface contamination and avoid cross-contamination; increase alertness in the workplace, avoiding rushing, distractions and walking on contaminated floors; use of slip-resistant shoes with proper maintenance; regular training to improve better understanding of the floor cleaning protocol; evaluation of the potential utility of slip-resistant mats and floor treatments; isolation of the work processes with higher risks of slips and falls; use of safety alert signs for slippery floors.

As future developments, different equipment should be tested under different working conditions since the most referred method is the BM II slipmeter, and more field research is needed to better understand the association between risk of slipping at work, shoe type and perception of slipperiness, through well-designed analytical studies.

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Risk Management in Personal Transfer Activities Using Aerial Baskets and Surfer Boats in Offshore Units

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Abstract Personnel transfer operations through aerial baskets and Surfer boats present serious accident risks when executed without proper accident prevention and control measures. These activities involve a wide range of occupational hazards that cause problems to the health and safety of the worker as well as hinder the performance of their work. The objective of this research is to carry out risk management based on the activities of transferring people through aerial baskets and Surfer boats, which consists of identifying the risks present in these activities, proposing measures to avoid accidents during this process, making this transportation a safe procedure. To do so, the Preliminary Risk Analysis (PRA) tool was used, listing the risks associated with these processes, including their causes, effects, classification and their preventive and control measures. From the studies carried out, it was possible to verify that the risks of accidents are predominant in these operations. It was observed that 73% of the risks indicated were classified as not tolerable and 27% classified as moderate. In this way, cable disruption, falls of people during transportation, mechanical collisions and decoupling of structures are risk agents that demand effective actions of prevention and control.

Keywords Transfer · PRA · Safety

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1 Introduction

The transfer of people in offshore operations consists of the movement of personnel between the vessel and the deck of the maritime drilling and/or oil production unit. Marine installations include fixed and mobile platforms, as well as floating production units and support facilities [1]. In the petroleum sector, there are different methods of transferring people in maritime environments, such as the personal transfer basket and the berth for the surfer type of boat, commonly used by oil companies [2].

In these personnel transfer activities, worker movement processes are of high risk, since the procedures performed expose crew members to injuries and damage to physical integrity. Besides the risks inherent to these procedures, it was also observed problems related to the breaking of crane cables, falls of people at sea and collisions between the transfer basket and the platform structure [3].

In the oil industry, risk management in a wide range of industry activities is important. In maritime transfer operations, the implementation of projects aimed at the safety of workers is crucial for the prevention of accidents that affect their health and physical integrity. The activities related to personnel transfer baskets and the berth for the Surfer boat involve physical, ergonomic and accident risks. Chemical and biological risks are not considered in this study. For the real success of these operations, it is necessary to adopt control measures that minimize the exposure of workers to the risks peculiar to these processes.

According to ABNT NBR ISO 31010 [4], the risk management structure will be responsible for defining procedures, policies and organizational arrangements that will ensure that risk management is incorporated at all levels of the organization. In this way, the organization should present pertinent policies and strategies regarding decision-making related to the risks present in the activities carried out. Thus, a good adoption of methods in risk assessment will imply an efficient risk management project.

In view of the above study, this research aimed to propose a risk management using the Preliminary Risk Analysis tool in the activities of transferring personnel in offshore units, as well as propose measures of control of the existing risks in order to collaborate so that the activities could be carried out more efficiently and safely.

2 Transportation of Personnel in Offshore Units

In the oil industry, operations in marine environments require constant transfer of workers. According to Botelho [3], in the phases of installation and start of operations, it is possible to observe that these activities occur more frequently. In this sense, since the establishment of these operations, the transportation becomes characteristic for the activities of embarkation and disembarkation in situations of exchange of shift, periodic maintenance, rescue operations, etc.

Personnel transfer activities are related to direct accident hazards. The types of transport to be used, according to Botelho [3], may be: small boats or boats, crew or support boats, bridges and ladders of accommodations, personal baskets and helicopters.

2.1 Ocean Structures—Staff Transport Basket

The personnel transportation basket consists of a form of transfer of workers using a specific basket driven by a crane that is present in offshore units to move people from a vessel to the deck of a platform and vice versa. In some situations, this method of transport is quite used, especially when there is a significant difference in height between the vessel and the platform. The personnel transport basket should be used when the transfer is strictly necessary and in cases where safer means such as helicopters are not available for use [5].

According to NBR 10876 [6], the personnel transport basket is “a device moved by means of compatible lifting, capable of transporting people from a maritime unit to a vessel and vice versa”. In relation to the types of baskets available on the market and most commonly used in the oil industry, Billy Pugh, Esvagt and Personnel Transfer Capsule baskets may be listed.

The Billy Pugh transfer basket is considered to be the most traditional as well as the most widely used. In this type of basket, workers are positioned outside the structure, which consists, from a general analysis, of a floating circular plate together with a mooring that serves as support for the workers [3].

The Esvagt-type transfer basket resembles the Billy Pugh-type basket, but presents as a difference the fact that the crew is positioned within the structure, which is advantageous, since it reduces the risk of accidents. This basket model features a metal structure that protects crew members against falling at sea [5].

The Personnel Transfer Capsule transfer basket is considered to be the safest and most modern. In this type of basket, the crew member is seated and secured with a seat belt. However, due to its high manufacturing and maintenance costs, this structure is not widely used as a form of transportation of workers [3].

The preliminary text of a regulatory standard on health and safety in oil platforms, published in the Official Gazette of the Union on 05/22/2013, SIT Ordinance No. 382, points out in its item 13.4, which refers to access to the platform by transport basket, the aerial transport should be carried out only under appropriate meteorological and oceanographic conditions such as visibility greater than 3 km, mild sea and wind conditions.

2.2 Ocean Structures—Surfer Boat

The transfer of personnel using the Surfer boat is carried out from the process in which the crew, transported by this type of boat, approaches and makes contact between the bow and the berth of this structure [8]. Through this connection, workers gain access to the platform exposed to fewer risks of accidents [5].

According to the preliminary text of the regulatory standard on health and safety in oil platforms, published in the Official Gazette on May 22, 2013, SIT Ordinance No. 382, points out in item 13.5, which refers to access to platform by boat of the Surfer type, the transfer of people by means of this boat should be made by the fulfillment of the following requirements: the berth should be designed by a suitable expert according to the legal terms of the process, besides being accepted by the Maritime Authority; sea, wind and visibility conditions should be conducive to carrying out the operation, whereas they will be checked and recorded in a specific document by the person in charge of the vessel.

3 Methodological Aspects

3.1 Research Characterization

Regarding the methodological aspects adopted in this study, bibliographical research was used, such as journals, scientific articles, books and official documents dealing with the subject matter.

The data of this research were obtained in two different ways. Initially, observations were made using photos and videos provided by the work team composed of petroleum and work safety engineers, an occupational safety technician and a supervisor. Then, once the risks intrinsic to the activity were observed, an informal interview was conducted with a work safety engineer and a petroleum engineering expert.

3.2 Application of the PRA (Preliminary Risk Analysis)

Once the data were collected, an analysis of the risks present in the transfer activities via basket and Surfer boat was carried out. These risks were listed according to cause, effect, frequency, and severity.

According to the ABNT NBR ISO 31010 standard, the preliminary analysis identifies the most significant risks and ensures that the resources will be focused on the most important risks. Thus, the preliminary analysis determines one or more modes of action, to assist in a more detailed risk assessment process.

Table 1 Frequency categories [7]

Category	Denomination	Frequency range	Description
A	Extremely remote	Less than 1 occurrence in 100,000 years	Conceptually possible, but extremely unlikely to occur. No historical references in the databases
B	Remote	Occurrence of 1 event between 100 and 100,000 years	There may already have been some historical, but not expected, event occurring during the life of the enterprise
C	Unlikely	Occurrence of 1 event between 30 and 100 years	Possible to occur over the lifetime
D	Likely	Occurrence of 1 event between 1 and 30 years	More than one life expectancy occurrence
E	Frequent	More than one event per year	Occurrence expected several times throughout the useful life

Table 2 Categories of severity [7]

Category	Type	Description
I	Negligible	Failure will not produce functional damage or injury or contribute to system hazards
II	Marginal	Failure will degrade the system, however without major damage or injury. It can be compensated or controlled adequately
III	Critical	Failure will cause injury, system degradation, and substantial damage or will cause unacceptable damage (requires immediate corrective action)
IV	Catastrophic	Failure will cause injury, death, or total loss (severe system degradation)

In this work, the PRA application was based on risk classification tables. The frequency categories are shown in Table 1. Once the hazards, their causes and their implications are identified, the frequency categories are defined and provide qualitative information on the frequency of occurrence of accidents based on the type of operation performed.

Table 2 shows the severity categories through a qualitative analysis of the degree of severity related to the consequences of possible accident scenarios.

A summary description of each risk category is presented in Table 3.

Table 3 Description of risk levels [7]

Risk category	Description
Tolerable (T)	No additional measures required
Moderate (M)	Risk kept under control. A new analysis is applied to evaluate the alternatives available for and to obtain an additional reduction of risks
Not tolerable (NT)	Risk not tolerable with existing controls. Alternative methods should be considered to reduce the likelihood of occurrence and its consequences

4 Results and Discussion

In this study, risks were observed in personnel transfer activities in offshore environments. The identification, classification and preventive measures associated with these risks can be illustrated in Table 4.

Table 4 Preliminary risk analysis in personnel transfer operations

Risks	Causes	Effects	Categories			Preventive control measures
			F	S	R	
Noise exposure	Due to crane operation	Stress, hearing loss, irritability	E	III	NT	MP 1
Heat	The transfer is performed under open area with exposure to solar radiation	Dehydration, sunburn, dermatitis	D	III	NT	MP 2
Fall at sea	Due to the unbalance of the crew during the transfer or operational errors of the crane	Injuries to the head, upper limbs, lower limbs and trunk	D	IV	NT	MP3
Mechanical collision between basket and platform	No observation of the weather, strong winds. Maintenance failure	Injuries to the head, upper limbs, lower limbs and trunk	D	IV	NT	MP4
Breaking crane cables	Mechanical failure, corrosion, operator error, failure to observe crane checklist items, lack of preventive maintenance, poor visual inspection	Injuries to the head, upper limbs, lower limbs and trunk	C	IV	NT	MP5
Slides and stumbles	Direct the look up or sideways, be inattentive	Injuries to the head, upper limbs, lower limbs and trunk	D	II	M	MP6
Sharp basket contact with platform deck	Due to operational errors of the crane, equipment failure, no observation of the weather, strong winds	Injuries to the lower limbs and trunk, including dorsal muscles, spine and spinal cord	D	III	NT	MP7
Uncoupling between the Surfer launch and the berth	Due to the sudden displacement of the vessel under adverse oceanographic conditions	Injuries to the head, upper limbs, lower limbs and trunk	D	III	NT	MP8
Interlacing of passenger during boarding	Inherent in personnel transfer activities	Lesions in the upper and lower limbs	C	II	M	MP 9
Crane pendulum movement	Due to weather conditions. Equipment failure	Injuries to the head, upper limbs, lower limbs and trunk	C	IV	NT	MP10

The categories under study are frequency, severity and level of risk. The frequency category (F) qualitatively classifies the different risk scenarios according to the frequency of occurrence of accidents. The severity category, however, provides a classification of the scenarios according to the degree of severity (S).

Finally, there is the classification of the level of risk, which is performed from the analysis of the frequency and severity of the different scenarios, categorized as tolerable (T), moderate (M) or non-tolerable (NT).

MP1 Use of personal protective equipment (PPE), such as ear protection devices.

MP2 Use of personal protective equipment (PPE) such as sunglasses with dark filters and skin protection cream.

MP3 Crane inspection and cargo handling accessories must be carried out. The flag shall be clearly identified during transport. Use personal protective equipment (PPE), such as safety boots with non-slip soles, lifejackets and a parachute-type safety harness that allows your anchorage to the basket.

MP4 Inspection of the crane and cargo handling accessories shall be carried out. Constantly signal to the crane during the transfer operation, especially in difficult crew viewing area. The crane operator and the signalman should be trained and thus have specific knowledge about the equipment and the type of activity performed. Use PPE’s, such as a helmet, safety boots with non-slip soles and a safety harness.

MP5 Visual inspection of the steel cables used during the transfer during corrosion and kneading. If necessary, substitutions should be made. Check that load lifting accessories such as slings, shackles and/or grommet are intact and consistent with the weight of the load and make sure that cables or chains are properly connected before subjecting them to stress.

MP6 Investigation of the general recommendations during the operation. Use of safety boots with non-slip soles and in good condition. Check that the destination is unimpeded, isolated and ready to receive the transport basket.

MP7 The flag must be clearly identified, performing constant signals during operation. The operator must have specific knowledge about the equipment and type of activity. A survey of the crane and load handling accessories should be carried out. Assess weather conditions.

MP8 Training of a support team and assistance to the crew that are being transferred, from training to this end, should be carried out. Verify equipment and structures that allow the proper attachment of the boat to the berth. Use PPE’s as a helmet, life jacket and safety boots with anti-slip flooring.

MP9 Use of appropriate clothing to avoid twisting it due to the use of large garments. The parachute-type safety belt should be fastened close to the body, avoiding entanglement. Training of crew members should be carried out before being exposed to personnel transfer operations via the basket.

MP10 Inspection of the crane, checking if the equipment is ready to be used. Find out if the wind and wave height conditions are favorable to crane operation

5 Conclusions

From the proposition of a risk management in the activities of transferring personnel in offshore units, it was possible to observe some of the main occupational risks present in these operations, which are physical and accident risks. Therefore, the application of a Preliminary Risk Analysis contributed to the determination of measures to be taken in order to eliminate or at least mitigate the environmental risks presented.

Since workers are exposed to risks during the transport operation, actions aimed at controlling these risks must be put into practice constantly. The risks of accidents related to falls, mechanical collisions and operational problems were preponderant in the activities. It was observed that 73% of the risks mentioned were classified as not tolerable. Thus, the proposed risk management should prioritize control actions for these risk agents. Thus, in relation to the transportation of workers, an advance study of the environmental conditions for transportation should be carried out, training the crew and crane operators and checking the conditions of the equipment involved in the operation. This way, it is possible to avoid accidents that bring negative consequences to workers such as personal injury or even damage to physical integrity.

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Application of Control Banding to Workplace Exposure to Nanomaterials in the Textile Industry

Delfina Ramos, Luis Almeida and Marco Gomes

Abstract Nanomaterials are now present in many consumer products, including textiles. They offer new technical and commercial opportunities but may pose risks to the consumers and to the environment and raise occupational health and safety concerns. The control banding approach for occupational risk management applied to engineered nanomaterials, according to ISO/TS 12901-2:2014, is a pragmatic approach useful for the control of workplace exposure to possibly hazardous agents with unknown or uncertain toxicological properties and for which quantitative exposure estimations are lacking. Nanomaterials are now often applied to textiles by means of textile finishing; in the present paper, a case study is presented in a finishing company involving two chemical finishes involving nanomaterials: mosquito repellency and antibacterial finish. The risk analysis concerned mainly four workers involved either in the preparation of the finishing baths and on the conducting of the stenter frame. Following the application of control banding method, measures to mitigate risks have been envisaged: appropriate ventilation and use of adequate personal protective equipment. Hazards related to one of the chemicals are higher and require also the use of a closed booth and a smoke extractor. The safety data sheets are

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the first source of information on how to handle and care for a particular product containing nanomaterials, but the information provided is still non-existent or very limited, in terms of the specific hazards and risks of nanomaterials.

Keywords Control banding · Nanomaterials · Textile finishing

1 Introduction

Nanotechnology became in the recent years an important tool to obtain innovative effects in different industrial sectors, ranging from food to transport. There are nowadays in the market many consumer products which incorporate nanomaterials, including garments and other textile products. In fact, Properties of nanoscale materials can differ from the properties of individual atoms, molecules, and bulk matter, allowing to create improved materials, devices, and systems that exploit new chemical, physical, mechanical and biological properties. The differences between materials at nanoscale compared to macroscale may also mean that they interact differently with the biological system. In fact, they may be more readily absorbed or even overcome more rapidly the physiological barriers of the body.

The regulating authorities recently started to put emphasis on the potential risks for human health, both in terms of consumer exposure and of occupational safety and health, related to the exposure of workers involved in manufacturing, processing and handling of consumer goods containing nanomaterials. Exposure to engineered nanomaterials has been associated with a number of health effects including pulmonary inflammation, genotoxicity, carcinogenicity and circulatory effects. In addition, the increasing use of nanomaterials, including for industrial purposes, raises specific concerns regarding their disposal at the end of their life cycle with the unavoidable release to the environment that may lead to indirect human exposure [1].

According to Purohit et al. [2], nanomaterials themselves constitute a new generation of toxic chemicals. As particle size decreases, in many nanomaterials the production of free radicals increases, as does toxicity. The number of commercial products and the number of workers potentially exposed to engineered nanomaterials is growing, as is the need to evaluate and manage the potential health risks [3].

Table 1 presents some hazards/sources of risk in occupational exposure of workers to nanomaterials.

The following general principles are suggested for the elimination or reduction to a minimum of risks associated with hazardous chemical agents [4]: design and organisation of systems of work at the workplace; provision of suitable equipment for work with chemical agents and maintenance procedures which ensure the health and safety of workers at work; reducing to a minimum the number of workers exposed or likely to be exposed; reducing to a minimum the duration and intensity of exposure; appropriate hygiene measures, reducing the quantity of chemical agents present at the workplace to the minimum required for the type of work concerned; and suitable working procedures including arrangements for the safe

Table 1 Hazards/sources of risk in occupational exposure of workers to nanomaterials [4]

Hazard/source of risk	Some risk factors
Inhalation of the agent	Toxicity of nanomaterial Physico-chemical characteristics of the material Concentration in the environment Exposure time Sensitivity of workers Selection or inappropriate use of protective equipment
Absorption through the skin	Location and extent of contact with skin Toxicity of the agent through skin contact Duration and frequency of contact Sensitivity of workers Inappropriate selection or use of protective equipment
Skin or eye contact	Inappropriate selection or use of protective equipment Inappropriate work procedure Wrong transfer procedure

handling, storage and transport within the workplace of hazardous chemical agents and waste containing such chemical agents.

These principles should particularly be adopted for chemicals containing nanomaterials. The hierarchy of risk management controls options should be the following [5]:

Isolate or Enclose: operations which involve the likely release of MNMs (manufactured nanomaterials) into the air should be performed in contained installations or in facilities that can be operated remotely from a protected area.
Engineering Control: processes where there is a potential for creating dusts or aerosols of MNMs should be carried out in areas with efficient local exhaust or extraction ventilation.
Administrative Control: working procedures and staff assignment to tasks should be developed so as to ensure safe handling of MNMs; adequate training and information should be provided to individual workers; an Emergency Management Plan should be established.
Personal Protective Equipment (PPE): PPE should be regarded as a "last resort" control measure or a supplemental option to be used in conjunction with other measures.

It is essential to know if the chemicals used contain nanomaterials. Some products emphasize this information in advertisements, as this may offer a technical or commercial advantage but for some other products manufacturers might not want to openly advertise this, either for confidentiality reasons or to avoid raising public concern. It can therefore be difficult to tell with certainty if a particular substance or product contains nano-forms [5]. It is essential to know if there are nanomaterials present in the chemicals used. This information should be found either on the product labels, in the safety data sheets and in the technical specifications. Unfortunately in many cases the safety data sheets do not include specific information concerning the health and safety risks related to the presence of nanomaterials. The current regulatory framework does not yet guarantee the traceability of the market and a unique regulation about the indication of the presence of nanomaterials on labels [6].

The textile industry is already an important user of nanotechnologies and there are a significant number of "nanotextiles" in the market. In most of the cases, special effects are obtained by the application of chemical finishes which incorporate nanomaterials. The most common nanomaterials used are Silver (for its antibacterial properties) and Titanium Dioxide (especially for UV protection and self-cleaning properties), but many others can be used, such as nanoclays, which grant flame retardancy and abrasion resistance [7]. The application of these chemicals in the textile finishing industry poses health and safety concerns for the workers, namely those involved in the handling of the chemicals from the warehouse until the textile finishing machines. A case study will be presented in this paper involving two types of finishes in a Portuguese textile finishing company.

2 Materials and Procedures

2.1 Control Banding

The control banding approach was originally developed by the pharmaceutical industry as a way to safely work with new chemicals that had little or no toxicity information. It is a pragmatic approach which can be used for the control of workplace exposure to possibly hazardous agents with unknown or uncertain toxicological properties and for which quantitative exposure estimations are lacking, which is the case of nanomaterials.

The major challenge in developing a banding control approach for nanomaterials is to decide what parameters to consider and what criteria are relevant to associate a nano-object with a control band, and what operational strategies to use. It is the producer or importer's responsibility to determine whether or not the product contains nanomaterials and to provide relevant information in the safety data sheets, labels, etc., according with existing regulations. In this way, companies and employees can use this information to identify hazards and implement appropriate controls.

ISO has developed a Technical Specification ISO/TS 12901-2:2014 for the use of the control banding approach in the management of occupational risks applied to engineered nanomaterials [8]. Control banding can be particularly useful for the risk assessment and management of nanomaterials, given the level of uncertainty in work-related potential health risks from nano-objects as well as their aggregates and agglomerates, even if they are greater than 100 nm.

The Control Banding process, according to ISO/TS 12901-2:2014, includes the following elements:

Information gathering. In case there is little or no information to guide decisions on the potential for a particular hazard or exposure, "reasonable worst-case assumptions" should be used along with management practices appropriate for those options.

Assignment of the nano-objects to a hazard band. Hazard banding consists in assigning a hazard band to nano-objects on the basis of a comprehensive evaluation of all available data on this material, taking into account parameters such as toxicity, in vivo biopersistence and factors influencing the ability of particles to reach the respiratory tract, their ability to deposit in various regions of the respiratory tract, their ability to elicit biological responses.

Description of potential exposure characteristics. Exposure banding consists in assigning an exposure scenario at a workplace to an exposure band, taking into account the physical form and amount of the nano-object, dust generation potential of processes and actual exposure measurement data.

Definition of recommended work environments and handling practices (control banding). The implementation of control banding can be made in two ways: proactively or retroactively. In the proactive approach, used in the present study, recommended work environments and handling practices may be defined on the basis of hazard banding as well as of fundamental factors mitigating anticipated exposure potential, e.g. propensity of the material to become airborne, the type of process and amounts of material being handled.

Evaluation of the control strategy or risk banding. Periodic and as-needed reviews should be implemented to ensure that the information, evaluations, decisions and actions of the previous steps are kept up-to-date.

Table 2 presents the hazard bands, according to ISO/TS 12901-2:2014. Details of the limits of each hazard band are presented in the hazard band allocation of the document [8].

In terms of Exposure Banding, ISO/TS 12901-2:2014 proposes four levels, from EB 1 (lowest exposure) to EB 4 (highest exposure). For manufacturing/production processes involving wet chemistry, as was the case studied, the levels of exposure banding suggested are EB 1 or EB 2. In case of nano-objects in suspension in a liquid, the choice on the quantity of depends on the amount of liquid and nano-object involved, as well as the potential of aerosol generation.

The measures proposed for the mitigation of risk are presented in Table 3.

ISO/TS 12901-2:2014 proposes the following control band matrix as a result of hazard band and exposure potential band, as presented in Table 4.

Table 2 Hazards bands [8]

Category	Hazard
HB A	No significant risk to health
HB B	Slight hazard—slightly toxic
HB C	Moderate hazard
HB D	Serious hazard

Table 3 Specific control measures for risk mitigation bands [8]

Level of risk	Control measure
CB 1	Natural or mechanical general ventilation
CB 2	Local ventilation: extractor hood, slot hood, arm hood, table hood, etc.
CB 3	Enclosed ventilation: ventilated booth, fume hood, closed reactor with regular opening
CB 4	Full containment: glove box/bags, continuously closed systems
CB 5	Full containment and review by a specialist: seek expert advice

Table 4 Specific control measures for risk mitigation bands [8]

Hazard band	Band of exposure			
	EB 1	EB 2	EB 3	EB 4
HB A	CB 1	CB 1	CB 1	CB 2
HB B	CB 1	CB 1	CB 2	CB 3
HB C	CB 2	CB 3	CB 3	CB 4
HB D	CB 3	CB 4	CB 4	CB 5
HB E	CB 4	CB 5	CB 5	CB 5

2.2 *Textile Finishing*

The case study presented in this paper concerns textile finishing. Data were collected in a Portuguese textile finishing company, especially devoted to knitted fabrics. This company applies for specific customers textile finishes which incorporate nanomaterials. Two chemical finishes studied have been identified. According to the safety data sheets, the hazard statements (H) and precautionary statements (P), according to the CLP Regulation (Regulation EC No 1272/2008), are the following:

Product A (Mosquito Repellent)
H319—causes serious eye irritation. P233—keep container tightly closed. P261—avoid breathing dust/fume/gas/mist/vapours/spray. P305 + P351 + P338—if in eyes, rinse cautiously with water for several minutes; remove contact lenses, if present and easy to do; continue rinsing. P337 + P313—if eye irritation persists, get medical advice/attention. P403 + P233—store in a well-ventilated place, keep container tightly closed. P501—dispose of contents/container according to local/regional/national/international legislation.

Product B (Antibacterial)
H302—harmful if swallowed. H318—causes serious eye damage. H332—harmful if inhaled. H410—very toxic to aquatic life with long lasting effects. P280—wear protective gloves/protective clothing/eye protection/face protection. P273—avoid release to the environment. P301 + P312—if swallowed, call a poison centre or

doctor/physician if you feel unwell. P305 + P351 + P338—if in eyes, rinse cautiously with water for several minutes, remove contact lenses, if present and easy to do, continue rinsing. P501—dispose of contents/container to approved incineration unit.

Both chemicals are delivered in cans in a suspension in aqueous form. Note that neither of the product information or safety data sheets mentions specifically that these two products contain nanomaterials, although this information is indirectly provided by the suppliers. In one of the cases, the information states that "(…) the remaining composition of the product is kept secret by the company".

The two chemical finishes are applied to cotton fabrics by padding followed by heat setting in a stenter frame. The risk analysis concerned mainly four workers involved either in the preparation of the finishing baths (starting on the warehouse of chemicals) and on the conducting of the stenter frame.

The operations performed by the four workers involved in the manipulation and application of these chemicals included: opening of the cans, weighing the quantity needed for each batch, transportation of the chemicals to the production process, transfer of the chemicals to the stenter frame (automatic dispenser), preparation and mixture, with water addition, and finally development of the finishing process in the stenter.

3 Results

Table 5 presents the results of the control banding process applied to the different tasks performed by the workers involved in handling product A (mosquito repellent).

For the product A (mosquito repellent), the hazard band HB B has been chosen, taking into account that this chemical can cause serious eye irritation. Exposure band EB 2 has been chosen because this chemical is in a suspension form, with low potential of aerosol formation but used in quantities higher than 1 L [8]. In the production phase, the exposure of workers to the nanomaterials is lower, so EB 1 has been chosen. The corresponding control band, evaluated according to Table 5, is CB 1 (natural or mechanical general ventilation).

For product A, he company has already implemented all measures suggested by this study, ISO/TS 12901-2:2014, and the product safety data sheet. For exposure

Table 5 Selection of control bands for product A

Task	Band of hazard	Band of exposure	Control band
Opening and weighing	HB B	EB 2	CB 1
Transportation and transhipment	HB B	EB 2	CB 1
Preparation and start	HB B	EB 2	CB 1
Production	HB B	EB 1	CB 1

Table 6 Selection of control bands for product B

Task	Band of hazard	Band of exposure	Control band
Opening and weighing	HB C	EB 2	CB 3
Transportation and transhipment	HB C	EB 2	CB 3
Preparation and start	HB C	EB 2	CB 3
Production (stenter)	HB C	EB 1	CB 2

control measures/PPE, workers wear protective glasses, 0.7 mm thick butyl rubber gloves, protective clothing and respiratory mask when vapours are released.

Table 6 presents the results of the control banding process applied to the different tasks performed by the workers involved in handling product B (antibacterial finish).

For the chemical B, the hazard band HB C has been chosen, taking into account that this chemical can cause serious eye damage, as well as other health problems. Exposure band EB 2 has been chosen because this chemical is in a suspension form, with low potential of aerosol formation but used in quantities higher than 1 L [8]. In the production phase, the exposure of workers to the nanomaterials is lower, so EB 1 has been chosen. The corresponding control band is CB 3 (enclosed ventilation: ventilated booth, fume hood, closed reactor with regular opening), CB2 in case of the production process (local ventilation: extractor hood, slot hood, arm hood, table hood, etc.).

For product B, the company has implemented the measures suggested by the product safety data sheet. For exposure control measures/PPE, workers wear protective glasses, nitrile rubber gloves, protective clothing and respiratory protection mask when vapours are released. The other measures that have been suggested by this study, according to ISO/TS 12901-2:2014, were not yet implemented.

4 Conclusions

From the present work resulted the suggestion of control measures for risk mitigation by the use of the control banding approach, based on the analysis of the work stations and the information given by the suppliers. It has been recommended to the company to carry out exposure measurements to chemicals containing nano-scale materials at the workplace and compare against normative and legal limits.

The main problem which has been faced is the lack of information for the products used in the safety data sheets, namely in terms of the concrete nanomaterials present and the corresponding specific hazards and risks.

With the development of a specific REACH registration system for nanomaterials, it is recommended that the suppliers of chemicals which incorporate nanomaterials include more information on the hazards and measures for risk mitigation in the safety data sheets, based for instance on the recommendations presented in ISO/TR 13329 [9].

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Safety in Urban Rehabilitation Works of Drainage Networks

Cristina Reis, Paula Braga, L. F. Sanches Fernandes and Carlos Oliveira

Abstract Rehabilitation is often associated with buildings, but it is done in innumerable works, namely hydraulic works, roads and railway infrastructures, buildings, among others. This, no doubt, allows preserving and maintaining the works within a level of service for which they were sized. This type of works has risks in its execution, reason why it is necessary to evaluate them and to investigate what preventive measures should be implemented to take care that the works of rehabilitation are done safely being one of the main objectives of this research work. The methodology followed was the follow-up of a work of rehabilitation selected for the drainage pipes of the rainwater in the city of Vila Real. This work was necessary to end the floods in the area. The work was monitored in order to analyze the risks and the preventive measures associated to the works safe execution, complying with the one required by Decree-Law no. 273/2003. It was concluded that in a work in which the safety plan is implemented, the accident risk is minimized.

Keywords Safety · Rehabilitation · Risks · Prevention · Pipes

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1 Introduction

The new construction phenomenon is beginning to stop being a paradigm and a great priority begins to be given to the rehabilitation of heritage. As management asset, it is increasingly essential, regardless of the type of work. Safety is a fundamental issue, whether in new works or rehabilitation works. There are increasing concerns about safety at work.

1.1 Rehabilitation

On the official *websit*e of the Lisbon City Council, it can be read that urban regeneration is the form of integrated intervention on the existing urban fabric, in which the urban and real estate heritage is maintained, in whole or in part, and modernized through carrying out works for the remodeling or improvement of urban infrastructure systems, equipment and urban or green spaces for collective use and construction, reconstruction, expansion, alteration, conservation or demolition of buildings [1].

Rehabilitation of buildings is the form of intervention designed to confer appropriate functional, structural and constructive performance and safety characteristics on one or more buildings [2].

According to Daniel Oliveira Lopes, infrastructure rehabilitation is nowadays defended by many authors as one of the best solutions to populate the urban centers of the big cities, since it presents immense economic and environmental advantages, namely, for those looking for a job in the cities, in order to avoid the use of private transport and adapt to urban transport alternatives [3].

It is also seen as a good option to reduce the negative economic impact that the fall in the demand for new construction caused in the companies of the civil construction and public works sector, constituting, thus, an excellent opportunity to be taken advantage of by the companies of the sector. Urban rehabilitation was a way for companies to find alternatives to the reduction of new construction [3].

2 Rehabilitation Advantages

Rehabilitation works play a very important role since it assists in the preservation of cultural and environmental values, while also bringing economic benefits.

2.1 Preservation of Cultural Values

The old groups of current buildings are of great importance for the history of cities and their inhabitants, since they can demonstrate, today, how the recent evolution of humanity was and how buildings have been continuously and successfully adapting the different ways of living in society [2].

Current buildings are the physical support of various aesthetic movements, architecture and art, over time, representing the relationship between man and art.

It is essential to preserve, beyond buildings, all kinds of infrastructures. It should be noted that there are infrastructures with a historical character, such as the "Aqueduto das Águas Livres" in Lisbon. Constructed between 1731 and 1799, by royal determination, the "Águas Livres" Aqueduct constituted a vast system for capturing and transporting water by gravity. Classified as National Monument since 1910, is considered a remarkable work of hydraulic engineering [4].

The decisive role of social processes is mirrored in the definition of disasters, for example given by ISDR (2004) as "… a serious disturbance of the functioning of a community or society causing human, material, economic or environmental loss exceeding the ability of the affected community or society to cope with its own resources" [5].

It should be noted that dangerous events threaten the efficiency of urban drainage systems. Examples of hazardous events are natural gas line leaks (e.g. in Guadalajara [9]). Several explosions of gasoline destroyed the sewers and streets. The initial cause was a galvanized steel tube that was corroded in a pipeline. Both pipes corroded and gasoline leaked straight into the main sewer. Similarly, road accidents with explosives involved have the potential to blow up sewage pipelines. In addition, excavations potentially damage pipelines during road construction and other infrastructures [7].

2.2 Environmental Protection

The reuse of a large part of the constructed elements has reduced the amount of demolition and reconstruction.

Reducing energy consumption in the production and application of construction products, reducing CO_2 emissions, and limiting the quantities of demolition products to be removed and destroyed will raise other environmental concerns.

Instead of using artificial industrial materials, the use of traditional, natural materials (wood, stone, sand and lime) was once again valued.

The possibility of reusing demolition products through their integration into the work to be rehabilitated, or other similar characteristics, is very important today. Every work must contain a waste plan [3].

2.3 Economical

The economic benefits of rehabilitation work are as follows [8]:

- Reduction of demolition costs;
- Reduction of license and fee costs;
- Easier project approval;
- Reduction of yard costs;
- Reduction of urban traffic disturbances;
- Easier placement of construction products;
- Reduction of quantities of new materials.

This means that even if unit prices for rehabilitation work are higher than new and corresponding jobs, the total cost of rehabilitation intervention may be less than that of a new building.

3 Case Study

3.1 Methodology

The purpose of this work was to analyze the risks and preventive measures to be taken into account in a rehabilitation work on drainage of rainwater, taking into account all the constraints existing in this type of work. This work methodology had to do with a first contact with the legislation, in the matter of hygiene and safety in construction work, namely Decree-Law no. 273/2003 of October 29, which reviews the regulations of the safety conditions and health at work, in mobile or temporary yards. The Municipal Council of Vila Real was then asked to follow up on such work in order to carry out a risk analysis and preventive measures. Follow up to the work was done from September 2015 to February 2016, through combined visits with the security technician, on a weekly basis. The work was located on the Street. Dr. Manuel Cardona, in Vila Real, and consists on the rehabilitation of the drainage pipes of rainwater in order to end the floods in this area. To avoid this phenomenon, it was necessary to change the old pipes, for larger ones and to connect them to a box on the CIFOP football field, which in turn will forward these waters to the Corgo River.

Prior to the start of work it is necessary to carry out a program of excavation work, which must be preceded by a preliminary study on the nature of the ground, the depth to be attained, the existence of buried infrastructures such as water, electricity, gas, etc.), the approximation of buildings and trees, accidental overloads and vibrations to be supported by adjacent land, the degree of humidity, as well as all other elements that could endanger people lives [8, 10].

3.2 Risks

In buried infrastructure works, the risks to which workers are subject are [11]:

- Burial;
- Level drop;
- Fall in height;
- Electricity and electrocution;
- Floods;
- Colliding with vehicles;
- Collision of machines;
- Other risks arising from interference with other underground pipelines (electricity, gas, water, etc.).

To avoid such risks, the developer build up the safety and health plan, for the project phase, that was later updated and evolved, throughout the assignment, as it may be seen. The following sub chapters take into account the implementation of the health and safety plan and the follow-up of the same.

3.3 Existing Infrastructures

It is essential to contact the various entities that operate public or private water, electricity, gas, telephone, sanitation, etc. services, in order to be aware of the location of pipelines that may exist in the zone [9].

Cutting a gas or voltage line can cause extremely serious damage. These can be avoided if the location of the pipes is properly marked, as shown in Fig. 1.

The behavior of the terrain may not be ignored in view of the action of rainwater infiltration. All the existing water in the excavation zone should be drained in order

Fig. 1 Piping passage in the work

Fig. 2 Placement of a shackle to aid in the flow of water

to avoid its action as destabilizing agent, as shown in Fig. 2, where the water is drained by the shackle and piped in the center of the ground.

3.4 Entivation and Its Prevention Measures

In ditches and wells of foundations, the ignition is made (metal or wood), so that the openings support the impulses produced by the terrain and the circulation of neighbors and vehicles. Of course, depending on the type of terrain found, these are either continuous (closed or blind) or discontinuous. They should always be sufficiently strong and properly tightened against the ground by means of wedges and anchors.

Usually, the props, the straps and the struts are elements that integrate a wood entivation.

As it can be seen in Fig. 3, it is necessary to maintain a clearance of approximately 0.60 m between the upper edge of the trench and the materials, or products, of the excavation. Impacts of the terrain increase with overloads, escalating the risk of landslides.

In order to reach the bottom of the excavations, access ladders between a maximum of 15 m should be used and it must be ensured that they extend beyond the upper edge of the trench, by at least 1 m, for reasons of safety for workers.

It is necessary to install footbridges, which may be of wood or metal, so that the crossing of the trenches is carried out safely.

As far as troughs are concerned, they must be opened in sections as small as they are compatible with a good work performance and for the shortest time possible to be covered with adequate compaction.

Fig. 3 Safety distance to the trench

3.5 Fencing of the Work

It is mandatory to effectively delimit the workspace, establishing the necessary signalling for the guidance of people and vehicles, as shown in Fig. 4.

Fig. 4 Fencing of the work

4 Conclusion

After monitoring the work under study, it was concluded that safety in rehabilitation works is extremely important for the prevention of accidents, both individually and collectively. In this work the implementation of the security plan was accomplished, and seems to be efficient since there were no accidents. Although important, the risk assessment process is rarely applied. However, this process is an added value for the project and, when applied, appears to result in benefits for all involved parties: in the design and execution of works [12].

The mere act of not complying with safety regulations can have serious consequences for both the employee and the rest of the team. In relation to the employer this also is harmed, since, it has responsibilities before its workers.

It is essential that there is training and supervision for this kind of works, as it helps to minimize risks and to comply with safety rules.

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Sustainable Safety Measures Applied in Construction

Cristina Reis, Eliana Carpinteiro, Paula Braga, L. F. Sanches Fernandes and Carlos Oliveira

Abstract The objective of this work is to perform an analysis of the construction methods and sustainable safety measures currently applied in construction. It also addresses the systematization of knowledge in the areas of sustainability and safety in construction. Sustainability has played a predominant role in our society over the last few years. The concept of sustainability is directly related to economic and material development, aiming not to harm the environment, using natural resources in an intelligent way so that they can stay in the future. The current economic crisis which has particularly affected the construction sector has led to the development of innovative measures that adapt to social, economic and environmental needs. Innovation in the construction sector can be made through improvements in technical choices, such as the use of better quality, the increase of new technologies and specialized personnel, improvement of processes, increase of energy efficiency, and increase of sustainable criteria.). In fact, such work often requires operations under

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different working conditions, which can lead to new risks or an increase in common risks. Many of the accidents caused by the new working conditions could be avoided by making the right decisions during the pre-construction phases and especially during design and planning.

Keywords Safety · Construction · Sustainability

1 Introduction

Sustainability has played a predominant role in our society over the last few years. During the 2000s, space and urban policy in the United Kingdom became increasingly concerned with the creation of sustainable communities. The focus of urban revival on security through design has been replaced by new, more holistic discourses that emphasize “community safety” and the ways in which the planning process can be overhauled to achieve this.

The current economic crisis, which has particularly affected the construction sector, has led to the development of innovative measures that adjust to social, economic and environmental needs. Innovation in the construction sector can be made through improvements in technical choices, such as the use of better quality, the increase of new technologies and specialized personnel, improvement of processes, increase of energy efficiency and increase of sustainable criteria. The new construction methods have to adapt new sustainable security measures. This is because it was necessary to think about what would have to be done to minimize the risks of applying new materials which, although more sustainable, create difficulties in terms of hygiene and safety in construction. For security leaders, this emphasis has been a mixed blessing. On the one hand, sustainability is consistent with the security mission of protecting people, products, and profits. On the other hand, the safety message is sometimes included by a sustainability agenda prone to poor definition and lack of focus, in some cases diverting attention and resources at the board level.

According to Eichholtz et al. [1], the increase in sustainable construction criteria reflects both popular concern and preservation of the environment, as well as changes in consumer and investor preferences. Most construction projects, based on sustainable practices, focus on reducing environmental impacts by optimizing natural resources and reducing waste generated in the construction process. However, Rajendran et al. [2] argue that the concept of sustainability must include the workers safety and health. This work had as main purpose to make an interconnection between the sustainable construction and safety in this type of works.

2 General Conditions

2.1 Sustainability

Sustainability is, in fact, a "process" aimed at finding the balance between the environment and the use of natural resources. Humanity, over time, has degraded the planet's natural resources so it is now necessary to carefully seek out and plan their consumption in order to ensure the existence for future generations.

There are several definitions of sustainability. The definition adopted by the World Commission on Environment and Development, in 1987, in the Bruntland Report [3]: "Our Common Future" is as follows: "Sustainable development refers to the human system's ability to meet the needs of generations present without compromising the resources and opportunities for the growth and development of future generations". To Calvente [4], in "The Modern Concept of Sustainability" it refers to a more comprehensive Swedish definition where a sustainable society is one in which "economic development, social well-being and integration are connected to a quality environment. This society has the ability to meet current needs without compromising the ability of future generations to meet their own needs. Kibert defined sustainable construction as the "responsible creation and management of a healthy built environment, taking into account ecological principles and efficient use of resources" [5].

It was in the 60 s that reports began to appear on environmental issues where they warn of sustainable development on the grounds of preserving the environment was made. Some of the most representative reports are: Rome Club Report: Growth Limits (1968);

- Stockholm Declaration (1972);
- Bruntland report: Our Common Future (1987);
- Rio Declaration (1992);
- Agenda 21 (1992).
- Europe Strategy 2020 (2010).

The Brundtland Report (1987) indicates a series of measures to be taken by countries to promote sustainable development, such as:

- Limitation of population growth;
- Basic resources warrantee (water, food, energy) in the long term;
- Preservation of biodiversity and ecosystems;
- Decrease in energy consumption and development of technologies using renewable energy sources;
- Use of new materials in construction;
- Control/restructuring of the distribution of residential and industrial zones;
- Use and consumption of alternative sources of energy, such as solar, wind and geothermal;
- Recycling of materials.

Table 1 Table related to the implementation of health and safety plans

From the point of view	Economic advantages
Construction Company	3
Insurance	21
Social	5

Source Reis [7, 8]

2.2 Safety

The term security derives from the Latin “securĭtas”, refers to the quality of what is safe or protected from any dangers, damages or risks.

The concept of work safety is the set of resources and techniques, applied to the prevention or correction, for the protection of people, the assets of a company and the environment, to eliminate the risks of accidents resulting from the work process or assignment. Accidents at work have high costs for workers and employers [6]. As such, it is important to adopt preventive behaviors and be informed about practices that can reduce and/or eliminate risks. It is worth noting that, through research on accident costs (Reis et al. [7], Reis and Oliveira [8]), it is possible to prove that it is highly advantageous to prevent accidents at work, such as it may be seen at Table 1.

3 Emerging or New Risks

For the Advisory Committee on Safety at Work [9] “new or emerging risks should be identified with the aim of developing knowledge about the impact on the health and safety of workers. This knowledge should determine the basis for preventive measures, including legislative aspects if necessary.

The construction sector is constantly evolving, whether for social, economic or technological reasons, etc., so it is necessary to analyze all recent information that reveals the importance of future risks by prior identification not only of emerging risks but also of the new causes of current risks. The European Agency for Safety and Health at Work defines “Emerging risk: any new risk that increases”.

By new risk is meant:

- The risk did not previously exist and is caused by new processes, technology or types of work place, or by social or organizational changes; or
- It is a persistent problem that is considered a risk due to changes in social or public perceptions; or
- New scientific knowledge that allows a longstanding problem to be identified as a risk.

4 Green Jobs

The International Labor Organization, in a recent report [10, 11], on employment opportunities presented by the green economy, states that the current model is unsustainable. In this context the development of a sustainable environmental economy can contribute to new jobs within green jobs (a job that contributes directly to reducing the environmental effects of business or the economy at large by reducing energy consumption and reduction of emissions, waste and contamination, and the conservation of ecosystems.

The move to a sustainable economy will be more important in the construction of new buildings and in the rehabilitation of existing buildings.

There is a growing trend among architects, engineers and builders to adopt new techniques in buildings that allow for greater sustainability of the surroundings by reducing energy and raw material consumption, decreasing greenhouse gas emissions, and decreasing and better utilization waste [12].

There are several ecological building certification models that are based on environmental sustainability and include various criteria such as location, energy efficiency and renewable energies, water use efficiency, conservation of materials and natural resources, quality of the interior environment and design and orientation.

With this new scenario in construction, changes in the construction processes, the introduction of ecological technology, ecological materials and an increase in certain operations related to the recovery of waste are assumed, which may not only benefit the environment as positive or safety and health of workers due to changing working conditions

5 Risks Associated with Sustainable Construction and Methodology

The methodology followed in this research work was based on a bibliographical research on the subject. In a second phase, the aim was to find examples of works in which sustainable constructive methods have been applied.

Lacourcelle [13] believes that in relation to the risks associated with the incorporation of clean technologies in buildings, an increase in the use of solar panels (thermal and photovoltaic), causes a considerable increase of risks due to the increase of works that are carried out in conditions. Solar panels are usually installed in the roof of buildings, which means a high risk of falling in height, not only in their installation but also in their maintenance. Since in some cases these installations are carried out by workers who are not familiar with work at heights, such as electricians, another risk related to this work is the electrical risk, especially when the electric power comes from both the general grid and the photovoltaic power grid. The use of solar panels is also associated with the risk of fire, as these

Fig. 1 Installation of the glass cover

panels, especially solar collectors can reach high temperatures and could act as a source of ignition. In addition, thermal solar panels have a dimension of about 1 m × 3 m and can be very heavy, making them difficult to handle during installation (Fig. 1) and can produce over-stresses, especially in the lower back.

Another important element to obtain a good energy certification is related to the installation of doors and windows for improvements of the insulation of buildings. This task, besides involving work at a height, may expose workers to the risk of electrocution, since the installation of windows or insulating elements sometimes suppose to work on scaffolding or in the building cover where the worker can find electric lines.

During insulation work to reduce heat losses, you may also encounter a risk of exposure to hazardous chemicals. For example the isocyanides in polyurethane foam which is traditionally used as insulation in buildings. Isocyanides may cause asthma and irritation of the respiratory tract and skin. Synthetic fiberglass is also used as insulation and contains glass fibers, which are made from silicon and can cause irritation to the eyes, respiratory tract and skin. Regarding ceramic fiber, it is known that they can cause cancer and lung fibrosis in animals. Replacement work on previously mentioned materials, traditionally used as insulation, for greener ones (wood fiber, clay, etc.) may increase the risk of exposure during material removal.

Another task that may become more important in terms of safety in the remodeling of old buildings in order to obtain better energy efficiency is the adequate management of the residues originated in the remodeling. The trend in management and legislation for sustainability is leading to an increase in the reuse and recycling of waste generated as a consequence of the constructive activities, and therefore the risks associated with these activities.

Regarding the environmental performance of building materials, and what they can achieve within a sustainable building, this depends on several parameters related to the product life cycle that will determine the environmental impact of the product from the placement to its elimination. Therefore, within the concept of sustainable materials are considered not only the safety of buildings, but also durability, energy saving, environmental protection, among others.

Wood is considered to be one of the most environmentally friendly building materials since, taking into account all factors of its life cycle, environmental performance is superior to other products used in construction: it requires less energy expenditure in production, is natural, biodegradable, recyclable, is an excellent insulation. However, Golinveau [14] considers that as one of the main concerns the fire safety of buildings and related to the materials used and the increased use of products made from recycled wood, using engineering techniques, reduces consumption of raw materials under construction, but has a worrying behavior in relation to fire.

Within the environmentally friendly building materials may also include derivatives of the use of industrial by-products, which may be included as certain additives for building materials; This is the case of coal ash which is added to the concrete. Coal ashes are a byproduct of coal combustion and may contain traces of arsenic, mercury and other substances that may be harmful to workers' health, especially in operations involving the drilling or demolition of these structures [15].

6 Conclusion

The new trends in building construction are undoubtedly responsible for improving the environment by introducing elements that allow for lower energy consumption, reduced emissions and better use of waste generated. However, the analysis made shows that this environmental improvement will not always be associated with an improvement in the safety and health of workers in the sector, since a rapid transition to this new form of construction can lead to a lack of control over the new working conditions of these green jobs. In fact, such work often requires operations under different working conditions, which can lead to new risks or an increase in common risks.

It can be concluded that there are some preventive measures to adopt:

- To study how the sector is applying legislation in relation to waste management in the coming years and to analyze the changes that may occur to processes, management, technology used, etc. this can help to anticipate certain risk situations that may be considered especially important in the future. In this sense, it would be interesting to know the reuse and recycling operations that may be introduced in the future as well as associated technology, and to identify risks associated with this new situation.

- Certain risks associated with sustainable construction work may affect workers who are not fully familiar with the working conditions in which they perform their tasks or with the use of the technologies and materials they use [16, 17]. The realization of information documents on risks in sustainable civil construction can help raise awareness among companies and workers to anticipate accidents and diseases associated with these works.
- The advantages of the sustainability-based construction model must be accompanied by adequate planning of the tasks and an adequate design of the workplace, considering the technological progress in the selection of materials, work equipment and work procedures. In planning also the operations of collection, separation, packaging, storage, reuse, recycling of waste during the construction process should be considered. In any case, the principle that should prevail both in environmental management and in the management of the risks posed by the waste produced in construction is prevention at source, i.e. selecting the materials, estimating the quantities required and planning the phases and processes of the to minimize the generation of waste and the risks to the health and safety of workers, by applying one of the general principles of prevention which is to eliminate the risk at source.
- Risks in the construction sector depend on the building materials used and the waste they generate. Therefore, in planning the purchase of materials, they must respect not only the requirements regarding construction safety and sustainability, but also requirements related to the health and safety of the workers who deal with them. Therefore, when choosing and buying the construction material, it is necessary to comply with Regulation 305/2011 of the European Parliament and of the Council on the marketing of construction products, for which the requirements for placing on the market, the form the characteristics of the products and the use of the CE marking on those products [18].
- Innovation in preventive techniques may also be necessary to avoid some of the risks that have been mentioned. For example: the implementation of ergonomic solutions during the handling of heavy elements, facilitate the installation of these elements and reduce muscle injuries caused in the course of work the use of highly resistant collective fall protection systems.

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Risk Management and Supply Chain Risk Management Procedures in Construction Companies

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Abstract This study aims to learn how the construction companies apply risk management practices and supply chain risk management to mitigate risk in this field of activities. The study tries to combine theory with practical findings. The methodology in this study is mainly based on analysis of information collected from a literature survey and interview carried out at three construction companies and one logistic provider company, to see how they apply risk management procedures and practices and supply chain risk management in their activities. It was realized that:

- All interviewed companies were aware of different kind of risks associated with their performance such as economic risk, environmental risk and last but not least health and safety risk.
- The complexity and uniqueness of each construction project causes that the experience from previously performed projects can be used only to small extent. Furthermore, companies have their own methods and tools for assessing and managing the risk. Instead of using commonly known risk tools and models, they intuitively predict the probability of different scenarios and try to ensure their operations by for example buying insurance or adding extra clauses in the contract.

Keywords Risk management · Construction risk management · Supply chain risk management

1 Introduction

Lambert et al. [1] define supply chain management as integration of business processes from the end user through original suppliers that provides products, services and information that add value for the customers. Risks in the supply chain are uncertainties associated with these information, material and product flows from

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supplier to the delivery of the final product for the end user. To get a successful supply chain it should be identified, assessed and analyzed properly to develop an appropriate risk management plan.

The concepts of the supply chain mainly has been developed around the manufacturing industry, so the construction industry, which is characterized by one-of-a-kind projects, site production and temporary organizations, did not get much benefits along with the development of this promising field. In this study, the present approaches to manage the supply chain risks by the construction industry are going to be discussed.

This study has been mainly prepared based on a project conducted in Chalmers [2]. The main issue covered in the study is risk management practices in the specific field of construction and the related supply chain. Also issues concerning risk distribution between stakeholders, affecting relationships with both customers and suppliers are elaborated on in this study.

2 Aim of the Study

The aim of this paper is to study how the construction companies apply risk management practices and supply chain risk management to mitigate risk in this field of activities. The study aims to combine theory with practical findings.

3 Methodology

This study has been carried out by a literature survey through collecting information about risk management procedures and practices and supply chain risk management applied in construction activities. In addition three construction entrepreneurship firms and one logistics provider were interviewed. The construction companies are different in size in terms of scope of activities and the construction logistic provider company provides logistics consulting and logistics operations on site, but sells no material. Their main task is distribution of materials on site. Since only one person per company has been interviewed in this study, it will not be possible to generalize eventual conclusions and to fully apply them in other contexts. However, attempts of making general conclusions for the construction industry will be made. As far as the interviews are concerned, required data was obtained from the respondents by means of asking a list of questions verbally. This list of questions has been prepared in assisting with an expert team. Each interview lasted about one hour. The interviews were recorded and transcribed. Gathered data was examined in search for patterns or significant differences in risk approaches of the selected companies. Findings were rewritten in the way to enable present data in the form of the case study. Afterwards comparison of literature and empirical data was performed to facilitate analysis and search for improvements.

4 Case Studies

In order to describe risk management practices three construction company and one logistic provider were selected. The logistic provider give service to the construction companies. The companies have activity in Scandinavian countries. The study was conducted through interview with the representatives of the companies.

4.1 Analysis of Case Studies and the Results

Construction industry is characterized by high degree of uniqueness. Every project is different in many aspects which implies hinders for planning and designing processes. Because of this substantial difference, projects material planning, selection of suppliers, delivery schedules and all the aspects of SCM (Supply Chain Management) are project specific. All mentioned above is making risk management extremely difficult because experience from the previous projects can be used to a highly limited extent. However, data gathered during the interviews demonstrate some similarities in risk management of all the construction companies.

Maylor [3] claims that an evaluation of potential risks has to be carried out already at an early stage of any project to decide whether it is worth pursuing or not. All the construction companies included in the research are following this strategy. The assignment of the construction company to the construction project is performed by tendering process. Each interviewed company is assessing the risk in the initial phase before the start of the project during preparation for the tendering. This helps to reduce uncertainty in the next phases in the project or evaluate whether it is rewarding to take the project by the company. After accepting the project penalty clauses are included in the contract, which is also a mechanism to reduce risk.

All the companies are highly aware of the negative impact of risk. Therefore they focus on a proactive approach by avoiding risk, or if it is not possible by reducing the risk instead of coping with its consequences. The risk assessment process is done by companies' own employees when their competence is adequate for performing it. In case the competence of employees regarding particular risk issues is too low, external consultants are employed. Despite the uniqueness of the projects construction, companies are trying to use universal approach to every project and adapt this general template to every particular case. It is worth mentioning that neither of interviewed parties has a central database of previous risk assessment documents. All of the risk assessment documents are kept separately.

Perception of the economic, environmental, health and injury risks as important is outlined by all the companies. Risks related to human safety and work environment are mitigated by special regulations and rules which are supposed to be followed by employees. Each company claims that safe work environment is of high importance. Considering weather, which is important factor in the construction process, there is a common view that it should be considered as accepted risk, because of lack of possibility to avoid its effect.

Taking into consideration supply chain risks, time, cost, quality and delivering precision are mentioned as very important factors. If there is some kinds of deviation in delivery, it may cause for instance delay in or wrong materials supply.

It is important to mention that all the links of supply chain can be a source of economic risks. Bankruptcy or loss of financial liquidity of either suppliers or customers is perceived as the highest threat. Risk assessment which is evaluating all the previously mentioned risks is part of the suppliers evaluation program, which is performed by the companies before collaboration initiation. However, this program is taking into consideration only the first tier suppliers (suppliers of construction company's suppliers are not taken into account).

Insurance against occurrences and an extensive risk assessment are among the most effective risk mitigation strategies. Moreover, the significance of frequent follow-up meetings on both the supply and the demand side is emphasized. Meeting with customers can cause changes within the project which imply reduction of tied up risks. Clarification of their expectations can be the other outcome of these control meetings.

Division of risk is an important aspect for all construction companies. They are trying to transfer the risk to external parties, and when it is not possible the project is often declined.

As a logistics company specialized in the construction was also part of the research, the risk management from the perspective of the logistics supplier is analyzed. In this case risk and uncertainty are avoided from the earliest possible moment. The suitability of the project is assessed before taking it. If the customer is trying to hire the construction logistics company at the moment when the problems already appeared, or when the circumstances are unfavorable, the company is rejecting the project or is charging a higher amount of money.

After accepting the project, it is initiated with planning and design phase. Specificity of the construction industry implies that risk management is project-specific as well. However, there are some common approaches. The company is offering fixed prices for their customers. Other risks are eliminated by applying clauses in the contract. In case of external delays, the construction logistic company will be charged by stop time. Material damage is perceived as a risk, therefore an insurance is bought. Personal injury is also stated to be a high risk and it is avoided by following rules and regulations.

It is important to mention that customers might perceive the construction logistic company as a tool helping to mitigate or to share the risk. Fixed price offered by the provider helps to transfer financial risk to the construction company. Moreover, employing external logistics supplier lets the construction company to focus on their core competence, which prevents them from performance loss or from so called 'scope creep' meaning that the main scope of the project is lost [3]. As the construction logistic company uses students as the main workforce, it gives the company flexibility in case of unexpected resource requirements. Students can work overtime or the company can employ more part-time workers when needed.

Concluding, the construction logistic company being an expert in the construction industry in using suitable tools to achieve higher performance in the whole project and to avoid or to minimize some risks.

To sum up, there are several aspects that might be common for the construction industry, summarized in Table 1.

A final comment is that involving all parties in the risk assessment process is regarded as important, still, not all construction companies do that.

According to the literature definition given in the literature says that the supply chain encompasses all organizations and activities associated with the flow and transformation of goods from raw materials, to the end user [4]. However, during this study it was found that the common practices in a construction industry is close relation only with those actors who are directly involved in the project. This means that management of supply chain is extended beyond single organization, still it does not encompass all the flow from the raw materials to the end customer.

It was realized that all interviewed companies are aware of different kind of risks associated with their performance such as economic risk, environmental risk and last but not least health and safety risk. As is stated in ISO 31000 [5], risk management is a process to identify, assess, prioritize and minimize risks. Interviewed companies try to assess different risks associated with the project as early as possible to decide about the feasibility and eventual extra costs associated with activities to minimize the risk. However, the risk management does not end up after the planning phase. During the ongoing project there are many everyday risks which workers have to face. Companies are aware of those risks and in addition to

Table 1 Common characteristics of SCRM (Supply Chain Risk Management) in the construction industry

• Every project is unique
• Assessing the risks during an early project stage (tendering)
• Focus on avoiding/reducing the risks instead of coping with the consequences
• Employing competent personnel, otherwise using consultancy services
• Time, cost and delivering performance/quality related risks are very important
• Low awareness of suppliers' suppliers
• Weather risks are perceived to be normal as they cannot be avoided
• Bankruptcy/loss of financial liquidity of suppliers/customer is the biggest economic risk
• Involving all parties, both suppliers and customers, in risk assessment process
• Regular follow-ups and meetings with suppliers/customers
• Transferring extensive risks to external parties, otherwise declining projects
• Understanding clients expectations, suggesting possible project improvements

giving safety education to all workers they hire external companies who organize the flow of materials on construction sites in a more scheduled way, i.e. the construction logistic company. Companies also try to assess *lessons learned*, meaning that after the project is finished they evaluate what has worked out well and what did not went well. This approach goes hand in hand with what Pinto [6] emphasizes in his book.

As described by Svensson [7] and Christopher et al. [8], the leaner and more integrated supply chains get, the more likely uncertainties, dynamics and accidents in one link affect the other links in the chain. This is especially true in the construction company since for each ongoing project there is a great number of suppliers who are supposed to deliver components at the right time, quality and quantity. Failure in one delivery can affect the whole construction site (known as *domino effect*) causing significant time delays. One way to mitigate this kind of risk is to hire external logistics providers. On the other hand, outsourcing such activities may cause higher risk. Thus the balance should be found where communication between actors enhance the good information flow.

The complexity and uniqueness of each construction project, emphasized by Dubois and Gadde [9], causes that the experience from previously performed projects can be used only to small extent. Furthermore, it was realized that companies have their own methods and tools for assessing and managing the risk. Instead of using commonly known tools like process mapping, FMEA or risk box model, they intuitively predict the probability of different scenarios and try to ensure their operations by for example buying insurance or adding extra clauses in the contract with suppliers.

5 Recommendations for SCRM in Construction Industry

From previous analysis, there are several suggestions that may be instructive for SCRM in construction industry, to achieve both internal and external success.

- Start to assess multiple risk factors at an early stage. This is beneficial for avoiding some foreseen risks and eliminate total losses.
- Create a database for risk management including SCRM.
- A holistic approach is essential for managing construction supply chain risk.
- Try to involve more tiers of the construction supply chain.
- Even though every project is unique, still strive to build up trust and long-term collaboration with suppliers.
- Communicate more effectively with customers. Whenever feasible, help customers to make a better choice in terms of material quality and cost.
- Explicitly include penalty clauses in the contracts in order to reduce irresponsibility cases.
- Insurance is a good service for construction industry. It is a way to transfer some unforeseen risks.

- Try to make some alternatives for the two uncontrollable scenarios—bankruptcy of both customers and suppliers as well as bad weather.

As mentioned above, construction industry is seen as the most complex industry due to its enormous uncertainty in a variety of tasks. Additionally, each supply chain is different and has to be analyzed individually. Combination of this two characteristics makes risk management in the construction supply chain extremely difficult. Therefore, managing these multiple risks in a proactive, holistic and collaborative way is vital for construction industry.

The methodology in this study is mainly based on concepts in literature and interviews carried out at four companies. The study focuses more on the general information about SCRM in construction industry instead of applying various risk assessment tools. This is due to the aim of the paper to get more knowledge from the real construction industry rather than assessing its supply chain risks.

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Safety Management in the Maintenance Works on Motorways Through DELPHI Methodology and Pareto's Concepts

José Silva and Carlos Rodrigues

Abstract Several researchers have developed a thematic approach on the need to improve safety management in the maintenance works on motorways in operation to achieve better goals on safety and in the use of resources. The use of instruments linked to efficiency and effectiveness can be one possible solution to this challenge. The main objective of the present investigation is to prove that it is possible to identify the main risky activities and safety measures contained in the A area curve and linked to the Pareto´s concepts. The methodology used was a DELPHI panel formed by safety experts from different areas on motorways. The statistic treatment was made through the computer programme IBM SPSS Statistics 24. The results show that it is possible to identify the 38 most dangerous risks linked to the most dangerous activities. It was also possible to identify the 44 most efficient and effective safety measures to prevent/avoid those risks. The main risks are related to running over, crushing and falling from heights. These risks can be mitigated or eliminated by the following safety measures: assignment and work follow-up, traffic diversion by road traffic authorities, protection equipment and signaling vehicles at the workplace, adjacent lane narrowing and the placement of guards and nets on top of support walls. The research conclusions show that the identified risk activities and the associated safety measures represent the 20% most dangerous risks and the 20% most efficient and effective safety measures with obvious relevance to the decisions about maintenance works on motorways.

Keywords Occupational safety · Risk assessment methods · Injury prevention

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1 Background

In the case of motorways in operation, new risks are arising from the need to maintain their operation combined with the traditional risks in the construction sector, exponentially increasing the hazards both for the workers and the users of these infrastructures. The use of effectiveness and efficiency tools can be one possible answer to this problem. Besides the inherent risks associated with the construction work or the activities that must be developed, conditions related to external factors cannot be forgotten. Climatic conditions, morphologic motorway factors, traffic type and drivers' behavior are examples of some problems that should be considered when analyzing risks. Different groups of researchers have conducted several lines of approach to this thematic area. Some researchers have conducted a systematic review of the relationship between effectiveness/efficiency and the management of Health and Safety (H&S) on motorways together with the main critical factors on H&S risk analysis [1]. The findings in this topic reveal the lack of consistency in these matters. Another research group focused their activity in the discovery of the most dangerous places to work in these infrastructures [2]. However, this second article only deals with construction activities on construction phase, without the interference of other critical factors not related to H&S. A third article by other researchers deals with the incompatibility and interference of construction activities on motorways, but once more without referring other constrains [3]. Yet, another group of researchers produced one article [4] where they identified the main dangerous maintenance activities that can occur on operational motorways. In this research, they have identified 36 activities as the 20% most dangerous. The next logical step in this line of research and based on the findings will be the identification of the most 20% dangerous risks and of the 20% safety measures and general prevention principles most suitable to risk mitigation or elimination.

2 Methodology

The research methodology is based on one concept, one validated method and one software tool. The fundamental concept utilized is based on the Pareto's Principle [5], which basically states that 80% of events come from 20% of the possible causes. This Principle adapted to our thematic area states that 20% of the most dangerous risks can cause 80% of the accidents related to the 20% most dangerous activities and 20% of the most effective and efficient safety measures and general prevention principles can mitigate or eliminate those risks. The selected method was the Delphi methodology. Besides being a validated one, developed by de RAND Corporation after the Second World War, this methodology has the objective of achieving a feasible consensus among experts. Some authors [6] consider this methodology as a valuable instrument to avoid conflicts among experts, make predictions, and identify a hierarchy of variables with relevance to the re-search. Other authors [7] consider this methodology as the most adequate to “research what does not exist yet” and suitable to PHD theses. This method requires the production of inquiries that must be answered by experts. The research carried out [6] suggests the adoption of the Kendall’s coefficient as the most suitable to be adopted by experts and of 0.7 as the minimum value to achieve consensus. When this value is not achieved, the experts receive information for each question about the following statistics elements: median, average, mode and standard deviation. After this step, they are asked if they want to review their score. In the present case, the initial assumptions were based on the research [4] where the 36 most dangerous activities were identified. Based on this data two inquiries were produced. According to requirements of some authors [7], thirteen experts were identified, all of them with complementary experiences in the same area of this research. The software tool used to achieve the response values consensus among experts was the computer program IBM SPSS Statistics 24.

3 Results

To reach a consensus among experts, it became necessary to produce and invoice one round for the first inquiry and two rounds for the second one. In the first inquiry, the Delphi Panel was questioned about the influence of the possible risks on the activities, risks related to the location of activities and the most efficient safety measures and general prevention principles that can mitigate or eliminate those risks. As for their location, the Delphi Panel identified eight places where the most dangerous risks can occur. Their locations can be seen on Fig. 1.

It is possible to see that 76% of the risks only concern two locations—plain lane and median strip. The number of risks in each activity shows the distribution and importance of each one. The results can be seen on Fig. 2.

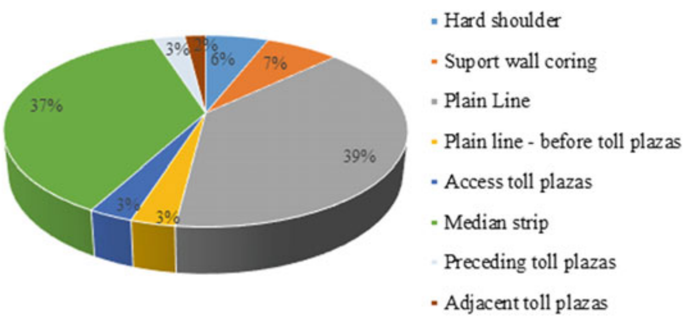

Fig. 1 Location of risks

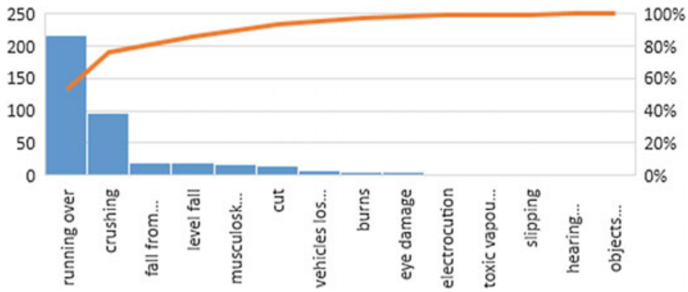

Fig. 2 Pareto's distribution of risks

Figure 2 also shows that 21% of the risks, specifically running over and crushing, represent 81% of the possible accident events. Concerning the possible applicable safety measures, the Delphi panel identified fifty-two types of safety measures. Placing in service protecting and signaling vehicles were elected as the safety measures to be employed more frequently. The goal of the second inquiry was to find the 20% most dangerous risks related to activities previously marked as the most dangerous and identify the 20% most effective and efficient safety measures and general prevention principles associated with the same activities. The Delphi panel identified 38 risks as the most dangerous. It is evident on Table 1 that 20% of the most dangerous risks are in almost 90% of the cases related to the risk of running over, followed by the risks of crushing and falling from heights. As for the safety measures and general prevention principles, the members of the Delphi panel concluded that the most efficient and effective safety measures achieved the number of 44. Figure 3 shows the influence of safety measures (concerning efficiency and effectiveness) on certain activities, while Fig. 4 shows the locals where the safety measures are more efficient and effective.

More than 25% of the safety measures that were found are related to repairs on safety guards, followed by repairs in expansion joints and emergency activities. Regarding the places where the safety measures are applicable, the flowing figure is very enlightening about that kind of information.

It is clear in this analysis that almost 80% of safety measures that present a higher possibility/level of efficiency and efficacy are associated with two places—plain line and median strip. More than 70% of the safety measures are associated with the risk of running over, followed by the risks of crushing and falling from heights. Through the indexation of general prevention principles to the safety measures, it is clear, that in all activity areas, more than 65% of the principles associated with the most efficient and efficiency safety measures are linked to the conception and organization areas and particularly in the most dangerous activities. The area where this fact is more evident, are associated with the working repairs on safety guards and the area where is less applicable are associated with repair works on ditches and drains (see Fig. 5).

Table 1 Risk and safety measures hierarchy and relationship

Rank safety measures/rank risk	Risk more dangerous/ activities description	Safety measures more efficient and effective
1/1	Running over—Access to working places through electronic toll "green way" at toll plazas	Creation of tunnels and upper passages to access the workstations
2/14,16,26	Running over—pavement ripping and pavement works without traffic diversion (motorway with two lanes or more in the same direction)	Dragging traffic by means of authorities' vehicles
3/1,2	Running over—Access to working place through electronic toll "green way" at toll plazas	Interdiction of crossing nonstop lanes at toll plazas
4/4,6,9,10,12,15,18,25,29,31	Running over—Motorway emergency activities in car accidents (motorway with two lanes in the same direction)	Dragging traffic by means of authorities' vehicles
5/30	Fall from heights—Working repairs on ditches and drains above support concrete walls with 2 m or more	Placing guards/nets on top of support walls
6/7,8	Running over—Cleaning or repairing works before the toll plaza and near the new jersey median strip or in the plain lane	Closing lanes on motorway with a protection and signaling vehicle, with a shock absorber stationed before the closing lane
7/3,5,28	Running over—Cleaning, cutting and deforestation on the median strip, with only a new jersey	Closing the roadside in the median strip and closing or narrowing the adjacent lane on motorway
8/17,19,21	Running over—Expansion joints repair works on motorways with two lanes or more and narrow hard shoulder	Closing the hard shoulder and closing or narrowing the adjacent lane on motorway
9/14,16,26	Running over—Pavement milling and pavement works without traffic diversion (motorway with two lanes or more in the same direction)	Placing protection and signaling vehicle, with a shock absorber stationed before the closing lane
10/23	Running over—Signaling assembly and disassembly works in construction works support on the median strip with only a new jersey	Dragging traffic by means of authorities' vehicles

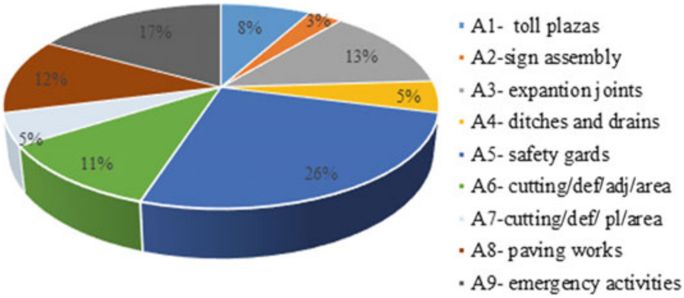

Fig. 3 Safety measures by activity

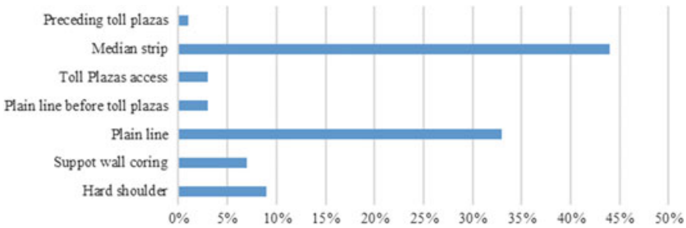

Fig. 4 Safety measures by location

Fig. 5 General prevention principles and the work conception and organization

The distribution of the general prevention principles by the risks are as follows: running over—77%; crushing—13% and falling from heights—6%. Once more, we have distribution according to the Pareto's Principle. Concerning the hierarchy of danger for each risk, its association with each activity and the relationship with the hierarchy of the associated safety measure, it is possible to see the first ten results on Table 1.

4 Discussion

In the present research, the findings related to traffic circulation risks show a result that is consistent with the work of some other researchers [8, 9]. In both cases, extreme weather conditions are important to a possible loss vehicle control. There is a clear consensus in the Delphi panel that the most dangerous situations deal mainly with running over, crushing and falling from height in locations as plain lane, median strip and above concrete walls. All these conclusions are in line with former researches, [10, 11]. Many of the activities concerning the risks of running over and crushing are directly linked to repairs on pavement, safety guards repair, access to working places and emergency activities. This last type of conclusions has already been addressed in a research [12] that has stated the difficulty of planning and implementing appropriated safety measures in the presence of psychosocial factors in the case of emergency workers. Another research [13] referred the need of safety integration on design phase concerning the different possible aspects that an operating motorway can present, such as the access to working places and the repairs that must be done in median strip or plain lane after. In many cases, if the designer produced a different type of layout at the toll plazas or had a different approach through a dialogue with maintenance contractors and owners, as suggested in some investigation [14], some risks could be avoided in future maintenance phases. As an example, a different layout of the median strip can avoid in many cases the risk of running over and crushing. The planning and phasing of the work, as an important part of the concept of the intervention on the working places, are clearly shown in the results, as one of the most important safety measures associated with general prevention principles in the areas of conception and organization.

By analyzing the results, it is possible to realize that there is a catalyzing effect that risks can produce namely between the factors associated with the loss of car control and the working maintenance risks. This effect had already been noted in a research [15] and it is one of the reasons why the experts pointed out the supervising by the authorities at working places, the traffic dragging by authorities' vehicles and the closing of the lane where works are taking place as well as the adjacent lane as fundamental factors to avoid the risk of running over and crushing. About the risk of falling from height, it can be partially solved if in the act of design conception, guards and nets.

5 Conclusions

The Delphi panel identified in the first place, 20% of the most dangerous risks associated with the most dangerous activities. That means 38 risks from global universe of the possible combination of risks. These risks consist mainly of running over, crushing and falling from height, occurring under bad weather conditions.

Their location is essentially on the median strip, plain lane and on top of sup-port concrete walls. According to the Delphi Panel, these risks represent more than 80% of the most dangerous ones in all possible situations. Concerning the relationship with the type of activities, it is possible to see that more than 30% of the identified risks are related to emergency activities. This fact was already stated in former researches [12], which claim that the traffic impact on emergency workers is one of the main risks for this kind of activity. According to the obtained results, it is possible to identify a ABC curve. The area A is related to the former identified risks. As for the safety measures and the associated general prevention principles, the Delphi panel agreed on a list of 44 (safety measures) as the representative of the 20% efficient and effective safety measures. They deal essentially with the supervising by the authorities, traffic dragging by authorities' vehicles and the closing of the lanes and adjacent lanes at working places, as well as guards and nets on top of support concrete walls. The working area that needs a bigger combination of safety measures and general principles of prevention to reach an acceptable level of efficiency and effectiveness is associated with emergency responses and the risks of running over and crushing.

Another relevant conclusion of the present research regards the kind of safety measures and general prevention principles chosen by the experts of the Delphi panel. In their opinion, all the choices of safety measures and general prevention principles related with conception, planning and organization have a higher efficiency and effectiveness compared with another kind of options. The difficulty in planning the activity in an acceptable time and the lack of a suitable design of the infrastructure are challenges that the technical and scientific community must address.

Another suggestion for a future research, which may be very useful to quantify the kind of work exposition that workers are subject to, is linked to the morphology of the motorway, the level of curves, inclination, the type of tunnels and viaducts.

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Part II
Occupational and Environmental Hygiene

Application of the International Chemical Control Toolkit in a Petroleum Research Laboratory at a Federal University in Rio Grande do Norte, Brazil

A. R. N. Araujo, C. G. Barreto, M. A. D. Souza, M. Cleber de Lucena and P. Câncio Neto

Abstract Chemical laboratories are responsible for important scientific advances in the world. Every day, chemists working in laboratories are exposed to hazardous chemicals. The methodology of the International Chemical Control Toolkit (ICCT) proposed by the International Labour Organization (ILO) concentrates the resources in the control of exposure to chemicals. The ICCT was used to evaluate chemical hazards in a petroleum research laboratory of a Brazilian federal university. The results show that 68.75% of the evaluated chemicals have average damage potential, 18.75% have low damage potential and 12.5% have a high damage potential. Thus, control approaches were proposed for all evaluated chemicals. The control measures proposed by the ICCT method for the chemicals analyzed include fume cupboard, general ventilation, good practices, and use of a glove box.

Keywords Laboratory chemicals · Petroleum · Classification and identification by risk substances, Products and materials

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1 Introduction

Chemicals have become essential in the day-to-day of modern life. When used properly, many chemicals can contribute significantly to improving quality of life. However, there are other chemicals that can harm health and affect the environment when used without proper care [1].

At home or at work, exposure to chemicals and drugs can lead to intentional and unintentional poisoning [2].

World Health Organization (WHO) estimates that in 2004 there were 4.9 million deaths (8.3% of all deaths) due to exposure to chemicals [1].

In Brazil, according to the Ministério Público do Trabalho (MPT) and International Labour Organization (ILO), a total of 107,378 accidents and 174 deaths involving chemical products occurred in 2017 [3].

The economic development of a country requires an increase in the capacity of the chemical sciences and consequently an improvement in the health and safety of laboratories [4].

The research and analysis carried out in chemical laboratories around the world allow important advances in the science and engineering of the countries. That way, the chemical laboratory has become an important center for the knowledge, development, monitoring, and control of chemicals routinely used in various industrial and commercial processes [4].

According to the National Institute for Occupational Safety and Health (NIOSH), the industry has been concerned about safety and health in its laboratories for many years. However, educational institutions take longer to adopt such practices in their laboratories [5].

Studies indicate that the rate of occupational injuries in the industry is higher in newly hired workers and decreases with experience. Therefore, in a school laboratory, students experience new activities, and the likelihood of accidents and injuries is high [5].

Still, according to the NIOSH [5], potentially fatal injuries can occur in laboratories.

One of the classic steps of Occupational Hygiene (OH) practice is the recognition of possible health hazards in the work-place [6]. The goal of Recognition of Hazard is to identify the existing risk factors and the conditions of occupational exposure [7].

For the ILO [6], when the health hazards are obvious, the control should be recommended, even before the quantitative evaluations are carried out. Thus, the classical concept of "recognition-evaluation-control" can shift to "recognition-control-evaluation" or even "recognition-control".

The need to develop requirements for the evaluation of chemicals in small and medium-sized enterprises led Health and Safety Executive (HSE) to develop a program called Control of Substances Hazardous to Health (COSHH) Essentials [8]. COSHH Essentials is based on the technique of Control Banding (CB) that categorizes risk and its control in bands [9].

The ILO and WHO recognized the potential of the pragmatic approach to the control bands of COSHH Essentials and initiated a process to adapt and promote it at an international level [9].

The ILO, WHO, HSE and the International Occupational Hygiene Association (IOHA) worked together to adapt COSHH Essentials in the form of a toolkit for the international application [9, 10].

In this international version called the International Chemical Control Toolkit (ICCT), the WHO through its Programme on Chemical Safety (PCS) has included the Globally Harmonized System for Classification and Labeling of Chemicals (GHS) as an alternative to the “R phrases” used in European Union (EU) [10].

In this perspective, this exploratory study applies the International Chemical Control Toolkit (ICCT) in an petroleum research laboratory of a federal university in Rio Grande do Norte, Brazil, with the main purpose of conducting a qualitative risk assessment and proposing its respective control measures.

2 Methodology

This study was exploratory and descriptive and based on the recognition of hazards and suggestions for their respective controls approach. Due to the fact that this study only encompasses an observational analysis of the work environments, there was no need to submit it to a Research Ethics Committee.

For the qualitative analysis of the hazards of the university petroleum laboratory, the International Chemical Control Toolkit (ICCT) was used.

In Brazil, the ICCT was translated and published in 2012 by the Fundação Jorge Duprat Figueiredo de Segurança e Medicina do Trabalho (FUNDACENTRO).

According to FUNDACENTRO [9], the methodology of the ICCT is composed of five stages:

Stage 1—Hazard classification of the chemical. At this stage, the substances are divided into six groups, where five danger groups from “A” to “E” relate the health damage caused by inhalation or ingestion of the substances. There is a group called “S” for hazardous substances when in contact with the skin and eyes.
Stage 2—The amount of substance that will be used. At this stage, it is identified whether the substance is a solid or liquid and the amount of the chemical used is classified as small, medium and large; according to ICCT parameters.
Stage 3—The amount of the substance that will spread in the air. At this stage, the spread of chemicals in the air are classified as low, medium and high according to their volatility (liquids) and dusting (solids).
Stage 4—The appropriate control approach. With the information collected in Stages 1, 2 and 3, it is already possible to define the most adequate control approach. The control approaches adopted by the ICCT are divided into: 1—general ventilation and good practices; 2—engineering control (local ventilation);

3—closure of the process; and 4—special (need for specialized advice to define the most adequate control measures).
Stage 5—The specific task control sheet. After the identification of the appropriate control measure, it is possible to find the form provided by the ICCT with guidelines for the task control sheet by the exposed worker.

The allocation of the substances to the hazard groups and their respective volatilities occurred from the GHS classification contained in the Material Safety Data Sheet (MSDS) of each substance.

The ICCT has 57 task control sheets and all of them have free access on the ILO website or the FUNDACENTRO publication.

All information collected in the 5 stages is noted on a checklist template provided by the ICCT.

3 Results

The research was carried out in a petroleum research laboratory of a Brazilian Federal University, located in the city of Natal, state of Rio Grande do Norte. In this laboratory researchers, professors, and students of graduation, masters and doctorate work.

The laboratory meets the scientific and technological demands of petroleum producing companies and service providers. Research and testing of the upstream segment of petroleum are carried out, among which we can mention works with drilling fluids, completing fluids, polymers, and additives, such as incrustation inhibitors, corrosion inhibitors and emulsions.

Visits were made to follow the routine of the laboratory and the activities developed. Research and tests performed in the laboratory vary according to the demand, however, independent of them, common tasks of the laboratory environment are present in the day to day. Among these tasks is the fractionation, weighing and mixing of chemical substances and/or solutions, washing of glassworks and analysis of products with the aid of equipment.

The use and variety of chemicals are wide. They are present in the different tasks carried out in the laboratory, from the preparation of solutions such as glass-washing. In this way, 18 chemical products were selected for this research.

Table 1 shows the 18 selected products. Only 16 of the 18 selected products were analyzed, since two products, potassium chloride, and sodium sulfate, are not classified as a hazardous substance or mixture according to GHS. For each analyzed product, the hazard group, the amount used, the form of propagation and its corresponding control measure according to the ICCT were determined.

For all chemicals analyzed the amount used was determined to be small, given that analyzes and tests are performed in small proportions.

In relation to the form of propagation in the environment, all 7 chemicals in the liquid state (1 to 7) have medium volatility. For products in the solid state,

Table 1 Chemicals analyzed by the ICCT

Order	Products	Hazard group	Control approach	Task control sheet selected
1	Fouling inhibitor	D & S	3	301 & Sk100
2	Hydrochloric acid (HCl)	C & S	2	201 & Sk100
3	Sulfuric acid (H_2O_4S)	C & S	2	201 & Sk100
4	Nitric acid (HNO_3)	C & S	2	201 & Sk100
5	Acetic acid ($C_2H_4O_2$)	C & S	2	201 & Sk100
6	Hydrogen peroxide (H_2O_2)	C & S	2	201 & Sk100
7	Acetone (C_3H_6O)	B & S	1	100 & Sk100
8	Sodium hydroxide (HNaO)	C & S	1	100 & Sk100
9	Ethylenediaminetetraacetic acid ($C_{10}H_{16}N_2O_8$)	A & S	1	100 & Sk100
10	Hydroxylamine hydrochloride (ClH_4NO)	D & S	3	301 & Sk100
11	Silver nitrate ($AgNO_3$)	C & S	2	201 & Sk100
12	Calcium chloride dihydrate ($CaClH_4O_2$)	A & S	1	100 & Sk100
13	Barium chloride ($BaCl_2$)	C	2	201
14	Strontium chloride hexahydrate ($Cl_2H_{12}O_6Sr$)	C & S	2	201 & Sk100
15	Iron chloride (Cl_2Fe)	C & S	2	201 & Sk100
16	Potassium bromide (BrK)	C & S	2	201 & Sk100
17	Potassium chloride (ClK)	Not applicable		
18	Sodium sulfate (Na_2O_4S)	Not applicable		

1 product was classified as medium dusting (8) and 8 products were classified as high dusting (9 to 16).

As for classification in groups of hazards, 3 chemicals (18.75%) were classified in hazard group "A" and "B" because they have a lower potential for causing health damage. Another 11 chemical products (68.75%) were classified in group "C", presenting average damage potential. In addition, 2 chemicals (12.50%) had the highest potential for damage and were classified as in group "D". Of the 16 chemicals analyzed, 15 products (93.75%) were also classified in the group "S", as these substances can cause damage when in contact with the skin and eyes.

The control approach 1 (general ventilation and good practices) should be adopted for the use of 4 (25%) chemicals. The control approach 2 (engineering control) must be adopted for the use of 10 (62.5%) chemical products. The control approach 3 (closure of the process) must be adopted for the use of 2 (12.5%) chemicals.

Skin and/or eye protection should be used when handling 15 (93.75%) chemicals of the total analyzed.

The task control sheets adopted are the same for the different types of chemical products handled in the laboratory, since the activities developed are similar. This observation is also valid for group "S".

For control approach 1 the task control sheet 100 was selected which deals with the general principles of general ventilation. For the control approach 2 was selected the task control sheet 201 that deals with a ventilated bench including fume cupboard. For control approach 3 was selected the task control sheet 301 which deals with good practice advice on the design and use of a glove box.

For control approach "S" the Sk 100 task control sheet has been selected which provides general advice on minimizing or eliminating the amount of material that comes in contact with the skin and eyes, as well as selecting the personal protective equipment appropriately.

Based on the control approach contained in the selected task control sheet, it was found that the laboratory searched did not have a favorable layout for the implementation of the general ventilation system. However, the site has three fume cupboard, allowing control approach 2 (engineering control) to be adopted not only for products categorized in control approach 2, but also for those categorized in control approach 1.

It was observed that although the place has the fume cupboard, they are not always used during the manipulation of the products that need this type of control.

The researched laboratory also has a glove box, an apparatus that allows the safe handling of products categorized in control approach 3. It was observed during the visits that occur the manipulation of products categorized in the control approach 3 in simple benches, without the protection.

4 Conclusion

The present research included one of the preliminary stages of Occupational Hygiene named Recognition of Hazards due to the nature of the already built facilities, including chemicals products and activities which were already being conducted.

The International Chemical Control Toolkit (ICCT) method was used to evaluate qualitatively the chemical risks in an petroleum research laboratory of a Brazilian Federal University. From the selection of a sample of 18 chemicals, 16 could be assessed by the method, with 2 products excluded from the assessment because of the GHS classification not to consider them as hazardous.

With the evaluation, it was possible to conclude that 18.75% of chemicals present a lower potential to cause damage to health (hazard groups A and B); 68.75% present mean damage potential (hazard group C); and 12.5% presented higher damage potential (hazard group D). In addition, 93.75% have the potential for damage to the skin and/or eyes (hazard group S).

Control measures were proposed for all analyzed chemicals. These proposed control measures were obtained from the task control sheets provided by the ICCT method. Among the proposed control measures, fume cupboard was suggested for most chemicals analyzed (62.5%), followed by general ventilation and good practices (25%) and use of a glove box (12.5%).

The limitations of the present study include the difficulty in obtaining the Material Safety Data Sheet (MSDS) of the chemical products in Brazil and the absence of quantitative evaluations that indicate the amount inhaled by the workers and the efficiency of the proposed control measures.

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Contribution Evaluation of "Branco Micaela" Granite Used in Facades, for the Safety of Workers

Paula Braga, João Gonçalves, Carlos Oliveira, José António F. O. Correia, J. F. Silva and Cristina Reis

Abstract The construction of a building must obey to some standards. In Germany, the standards that are used are DIN standards. Transgranitos, a Portuguese company, located in Vila Pouca de Aguiar, in order to be able to export facades of "Branco Micaela" granite, had the need to test the granite to meet this standards, namely, DIN EN 13364:2002-02 and DIN 52108 standards. In this paper we present the test results that Transgranitos needed to perform to meet the German requirements and the motives that make them so important in a safe building construction.

Keywords Granite · Facades · Transgranitos · DIN

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1 Introduction

The subject of the present work is the regulation of the properties of granite for use in facades. Natural stone is one of the materials that, due to its resistance, durability and aesthetic quality have been used since the beginnings of mankind. Nowadays, due to the technological evolution there is a wide variety of stones for all type of coatings. The use of granite on facades is regulated to meet the parameters of quality, durability and resistance. In this article it was proposed to study the "Branco Micaela" granite and to determine if it satisfies the parameters required for its use in facades, according to German legislation [1, 2] (Fig. 1).

2 Granite

2.1 Branco Micaela

The granite quarries of "Branco Micaela" are located in the massive granite of Aguiar da Beira, in Guarda district, Portugal. It is light, grey granite, and its grain size is fine to medium. This granite consists essentially of two micas and it is a homogeneous material. The observed heterogeneities, biotitic lineages and enclaves are uncommon and generally present a reduced size, thus not affecting the commercial value of granite [3] (Fig. 2).

This stone is especially indicated as building stone, countertops, sinks, monuments, pool coping, sills, ornamental stone, interior, exterior, wall, floor, paving and other design projects. It is also called Branco Aguiar Granite, Blanco Michaela Granite, Blanco Miquaela Granite, Branca Michaela Granite, Branco Micaella Granite, Branco Michaela Granite, Branco Micaela Granite, Granito Branco Micaela. Branco Micaela can be processed into polished, sawn cut, sanded, rock faced, sandblasted, tumbled and so on [4].

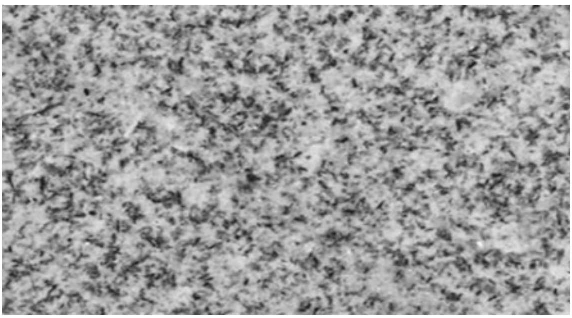

Fig. 1 Granite "Branco Micaela"

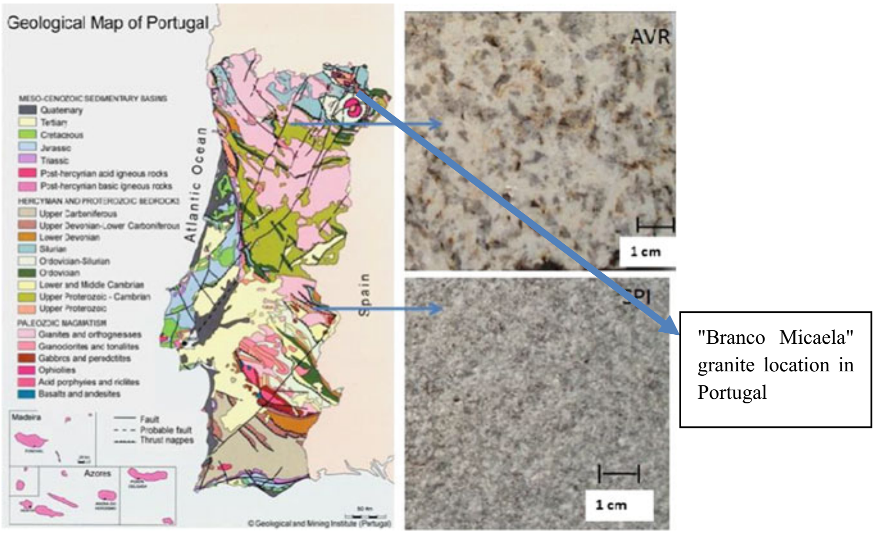

Fig. 2 Geological map of Portugal (LNEG edition) with identification of the studied granite [11]

2.2 Transgranitos, Lda

Founded in 1990, Transgranitos - Mármores and Granitos do Alto Tâmega Lda., is located in Trás-os-Montes, with its headquarters in Telões, Vila Pouca de Aguiar. It is inserted in a land of 50,000 m^2. It began as a company of extraction and transformation of granite, for decorative and coating purposes, to be used mainly in civil construction. Later, in 2009, it was complemented the range of offerings with marbles and limestones. A new unit was built for the processing of these raw materials. In addition to the processing of raw materials from quarries, it was experienced the reception and processing of rocks from other sources, both National and imported from Europe and other Continents. Transgranitos produces all kinds of surface finishes: polished, softened, buffed, flamed, sanded, shredded or sawed. Recently, the company also offers the textured finish, which runs on numerical control equipment and can take on a variety of forms.

2.3 Type Area

DIN standards (“Deutsches Institut für Normung”) are the technical standards for the quality assurance of industrial and scientific products in Germany. These represent regulations that operate on commerce, industry, science, and public institutions related to the development of German products. DIN performs the same functions as international standards such as ISO.

In order to comply with the DIN standards, Transgranitos had to submit the “Branco Micaela” granite to laboratory tests to verify that the material met the German quality parameters. For a stone to be applied on a facade it must comply with the following standards: DIN EN 13364: 2002-02 and DIN 14157 [1, 2].

The DIN EN 13364: 2002-02 standards [1], are used to determine the breaking load on a hole in the ventilated facade from natural stone. The load that the stone can carry in the hole of the facade is determined by mechanical tests made in the laboratory. If the stones meet the parameters of the standard they can be used in ventilated facades, thus deciding the installation and anchoring options of the corresponding natural stone facade.

DIN EN 14157 [2], is used to test abrasion resistance. The facades as they are applied outdoors are in contact with several agents that may cause erosion. As such, this standard serves to prevent the stone failure during the lifetime of the façade.

3 Experimental Test

The tests set out in this work have been carried out in the laboratories of the “DAkkS Deutch Akkreditierungsstelle GmbH”. A German accredited laboratory D-PL-11117-01-00, certified by DIN EN ISO 9001, DIN EN ISO 14001 and OHASAS 18001.

3.1 Din En 13364: 2002-02

For the certification of “Branco Micaela” granite, according to DIN EN 13364: 2002-02 [1], parallel pieces were used, with dimensions of 200 mm × 200 mm × 40 mm. A hole with a diameter of 10 mm was made in the parallel pieces. The sample was fixed in a dowel, made with cement, as it may be seen on Fig. 3. In total, about 10 samples were used.

A force was applied in the dowel until it reached the breaking load (Table 1).

In this table **d** is the thickness of the sample, **d1** is the distance to the hole and **bA** is the maximum size rupture, relative to the dowel center.

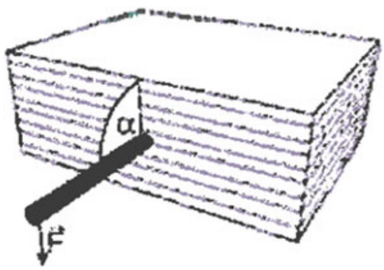

Fig. 3 Test specimen [1]

Table 1 Results of the tests for DIN EN 13364: 2002-02

Sample nº	Dimensions at breaking point (mm)			Fracture load	
	d	d1	bA	N	In xi
1	41	14	38	3900	8.269
2	41	12	50	3000	8.006
3	41	14	46	3750	8.230
4	41	15	57	3550	8.175
5	41	14	47	4000	8.294
6	41	14	42	3800	8.243
7	41	14	48	4150	8.331
8	41	14	49	4500	8.412
9	40	14	45	3750	8.230
10	40	14	48	4050	8.306
			Max 57		
Mean value				3845	8.249
Standard deviation				396	0.108
Variation coefficient				0.103	0.013
Lower expected value					3052

3.2 DIN EN 14157

For the certification of "Branco Micaela" granite, according to DIN EN 14157 [2], parallelepipeds were used, with 71 mm × 71 mm × 25 mm dimensions. In this kind of tests only 3 samples were used to verify if the rock meets the parameters (Fig. 4, Table 2).

Fig. 4 Abrasion test

Table 2 Table test results for DIN EN 14157

Sample nº	Dry bulk density g/cm^3	Abrasion loss cm^3/50 cm^2
1	2.61	5.0
2	5.59	4.4
3	2.59	5.0
Mean value	2.59	4.8

4 Workers Safety

Mining industry due to its great technical challenges continues to be one of the main high-risk industries. It is essential to take care of the safety of workers in quarrying and processing [5]. There is the risk associated with the inhalation of dust particles, namely silica, which are released, as it may be seen in the previous chapters, quite considerably, and have dimensions in the order of nanoparticles. These particles, that are often not seen, will enter the airways and after a few years will have serious consequences for the health of workers. Silica exists in the composition of the granites in about 48–60%.

The effects of exposure to silica, especially crystalline silica (0.5–10 µm), have been associated with silicosis (a form of fibrotic lung disease), emphysema [6] and was considered as a carcinogen by the International Agency for Research on Cancer in 1997 [7]. Although there are other sizes of particles released, the effects of chronic exposure to nanosilica (<100 nm), for example, is still controversial [8].

Silicosis is one of the most important professional/occupational diseases according to the regulatory decree of 76/2017 of 17 July. There are also risks associated with noise and vibration, caused by machines operating in this type of industry. Risks associated with ultraviolet radiation, particularly in the summer, thermal discomfort caused by heat and intense cold. Muscle skeletal injuries associated with handling of loads made without any care, entrapment/crushing, as well as falls level or even height.

OSHA respirator regulation mandates that employers ensure that workers are trained annually so they can understand the importance of respiratory protection and give a course how to properly use and take care of their equipment. This education consists in [9]:

- Why respirators are needed;
- What protection a respirator can or cannot offer;
- How to properly inspect, put on, take off and use a respirator;
- How to perform a "user seal check";
- What to do in emergency situations, including what to do if the respirator does not work properly;

- How to recognize medical signs and symptoms that may limit or prevent workers from using a respiratory;
- How improper fit, use or maintenance can reduce effectiveness;
- Maintenance and storage procedures.

Respirators should be checked before each use and during washing, and users must follow the manufacturer’s user advices for specific inspection and conservation procedures. Emergency respirators should be inspected at least monthly and before and after every use. Consider issues like:

- Respiratory function;
- Tightness and connection;
- Pliability of elastomeric parts;
- The condition of various parts including the facepiece, head straps, valves, connecting tube, cartridges, canisters or filters.

It is necessary for workers to wear respiratory protective devices to protect the respiratory tract; these must be dust masks of the combined type, as shown in Fig. 5. These masks can protect main diseases associated with the inhalation of hazardous dusts like Benign pneumoconiosis, pneumoconiosis, pneumonitis, mesothelioma of pleura and lung cancer [10].

This type of equipment cannot, and should not, be shared by workers. Masks must be appropriate to the type of agent to which workers are exposed. Before use, check the belts, the seals, the validity, the condition of the belt. During the exposure period the mask should not be removed [13].

Fig. 5 Anti-dust masks—Elettro Respiratori Cleanspace-2 [12]

5 Conclusion

The tests carried out allowed Transgranitos to produce and export facades of “Branco Micaela” granite to Germany, since it was determined that they comply with DIN standards.

Breaking load at dowel-hole tests should be one of the studied characteristics when stone is applied in a ventilated façade and the obtained results show that “Branco Micaela”, presents average breaking values of 3845 N.

The mean abrasion loss was determined as 4.8 cm^3/50 cm^2 for a dry bulk density of 2.59 g/cm^3.

Emphasis is placed on the need for workers to use personal protective equipment when working in quarries, or extractive industries, as it is found that airborne particles are very small in size and can affect the airways.

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Dust, Radon and Radiation Exposure in Environmental Remediation Works of Old Mine Sites

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Abstract The legacy of past radium and uranium mining waste in Portugal is currently dealt through an environmental remediation program for old mine sites which aims to prevent waste dispersal and radioactive contamination of the environment. In this paper radioactivity of waste materials and radiation exposure at uranium legacy sites are described and it is concluded that remediation workers might be exposed to radiation hazards. Furthermore, works involving clean-up of mine sites and milling facilities, radioactive waste transfer, and treatment of contaminated mine water may have environmental radiological hazards associated and may originate radiation exposure of members of the public as well. It is concluded that a radiological risk characterization shall be done and appropriate radiation protection measures shall be implemented in accordance with the EU Directive 59/2013 recently entered into force.

Keywords Uranium mines · Radiation exposure · Environmental remediation

1 Introduction

Wastes from uranium production contain radionuclides, mainly those of the uranium radioactive decay series, and often in high activity concentrations. Exposure to these radionuclides for long periods and uptake of radionuclides through inhalation and ingestion may give rise to excessively elevated doses of ionizing radiation. Exposure of human beings to ionizing radiation is regulated both at

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international level by UN organizations such as the International Atomic Energy Agency (IAEA), World Health Organization (WHO) and International Labor Organization (ILO), at the European Union (EU) level, and at national level (Decree Law nº 222/2008). Regulations, including those on annual radiation dose limits, classification of exposure, and individual radiation monitoring were adopted to protect human beings from the harmful effects of ionizing radiation. These regulations apply to nuclear industries as well as to non-nuclear industries and other human activities where exposure to naturally occurring radioactivity may occur (Directive 59/2013 EURATOM) [1].

In Portugal about sixty mines of radioactive ores were operated during the 20th century. The last uranium mine and mill ceased activities in 2001 and, over the years, radium and uranium mining and milling facilities closed without proper decommissioning. Wastes and facilities were left unattended, originating a legacy of hazardous and radioactive materials with potential for harmful impacts on the environment and on the population health.

The radioactive contamination of mine sites and industrial facilities, as well as radiation exposure of the public in their vicinity were assessed in projects carried out in the 90s and 2000s, in particular through the MinUrar project [2, 3]. Based on the conclusions from this assessment a specific programme was approved by the government for the clean-up of old mine sites and environmental remediation, i.e., for proper mine sites decommissioning and proper waste management [2, 3]. This environmental remediation is an ongoing programme, actually encompassing old mines and milling facilities of radioactive and non-radioactive ores [4]. Through this programme, vast engineering works were and are commissioned to civil engineering companies and workers are hired to implement clean-up of mine sites, transfer of mining and milling waste, decontamination of facilities, and other decommissioning activities.

Radiation exposure hazards associated with such environmental remediation activities and radiation protection of workers are discussed herein under the perspective of the most recent European Union Directive on radiation protection against the harmful effects of ionizing radiation [1]. This EU Directive entered into force in February 2018.

2 Uranium Tailings and Environmental Radioactive Contamination

The uranium mining legacy in Europe, where several countries have been producers of radium for cancer hospitals and later of uranium for nuclear energy, was recently assessed globally [5]. In Portugal, a vast survey of uranium mining and milling waste materials and their characterization was performed in the framework of projects, including the MinUrar project, and in the context of research activities [6–16].

Waste materials from uranium mining and milling are radioactive. Uranium milling tailings generally contain the highest radioactivity levels, as shown in Table 1 for uranium related materials from various sites. Although uranium isotopes themselves are still present in milling waste, in general the higher concentrations are those of the uranium daughters, such as thorium, radium, radioactive lead, and polonium [6, 8].

Due to uranium daughters present in wastes (e.g., ^{226}Ra, ^{214}Bi, ^{214}Pb, ^{208}Tl), uranium waste piles are radiation emitters and are the main contributor to the ambient radiation dose (external radiation dose). Exposure to such radiation might significantly impact humans and non-human biota in the neighborhood. For example, on top of Urgeiriça waste pile (Barragem Velha), before placing a cover, the beta-gamma dose rate was 7.5 μGy/h at 1 m above ground, which was 30 times higher than the natural radiation background in the region, 0.25 μGy/h. Furthermore, in uncovered mining and milling waste piles, radium (^{226}Ra) is easily dissolved and transported by rain water and thus can be dispersed in the environment and reach agriculture soils and rivers, such as verified in the Urgeiriça and Cunha Baixa areas [9, 10]. With time, waste piles generally become anoxic inside, and the rain water that percolates through the waste may still dissolve radium, and also other radionuclides although in less extent, generating leachates with very high radioactivity [11]. Radium in uranium mining and milling waste is the more mobile of radionuclides and the most likely to be ingested either with water or locally produced foods [16–18]. Besides radium, other radionuclides such as ^{230}Th, ^{210}Pb and ^{210}Po, although less water soluble are present in high concentrations and may also enter the food chain [16, 17].

The presence of ^{226}Ra in high concentrations in milling tailings, also originates large activities of the radioactive gas radon (^{222}Rn) which partly escapes to the atmosphere and might be inhaled. Likewise, dust particles from uranium waste piles may be suspended by the wind or by the re-work of such waste piles, increasing the dust load in the air. Inhalation of these dust particles contributes to radiation exposure of lungs.

In some former uranium mining areas the contamination of groundwater occurred and water from wells become radioactive and acidic [10]. An assessment of the radiation dose through ingestion of locally produced food, mainly vegetables and fruits from the kitchen gardens irrigated with contaminated water from wells, and consumption of local water was performed for Cunha Baixa village [18]. Radiation doses received by the inhabitants of this village through ingestion indicated that, through this exposure pathway, inhabitants could receive radiation doses exceeding the radiation lose limit if 1 mSv/year which advised to close wells and to provide an alternative supply of water for irrigation [18].

It was concluded that to prevent further environmental contamination and reduce the exposure of the population to radiation from uranium waste materials, some type of remedial action was needed. Several remediation measures and engineering works have been implemented by the company in charge [4].

Table 1 Radionuclide activity concentrations (Bq/kg ± 1 SD) in uranium waste materials from mining and milling sites, Portugal. Concentrations in a forest soil from the region are shown for comparison

Mine site (city)	^{238}U	^{234}U	^{230}Th	^{226}Ra	^{210}Pb
Forte Velho (Guarda)	4360 ± 130	4765 ± 140	18,570 ± 1190	20,625 ± 1030	24,730 ± 1620
Reboleiro (Trancoso)	29,470 ± 1420	28,880 ± 1390	23,520 ± 1590	13,180 ± 620	16,020 ± 1060
Quinta do Bispo (Mangualde)	13,717 ± 470	13,028 ± 447	26,729 ± 1544	3259 ± 264	4272 ± 270
Urgeiriça (Nelas)	2530 ± 94	2876 ± 105	10,337 ± 598	24,717 ± 2039	20,354 ± 680
Forest soil (Guarda)	400 ± 10	400 ± 10	440 ± 30	450 ± 40	410 ± 20

3 Purpose and Goals of Remediation Works

The long life of radionuclides contained in milling tailings, such as ^{230}Th ($T_{1/2}$ = 75,400 y) and ^{226}Ra ($T_{1/2}$ = 1600 years) indicate the potential for a long lasting contamination source. With time, the dispersion of radionuclides could create environmental contamination and compromise surface water, groundwater, soils, and other natural resources. This environmental contamination leading to enhanced radiation exposure of the population at the Centre-north of Portugal was considered a non-acceptable radiological risk and recommendations were made for implementation of environmental remediation measures capable to keep the radionuclides out of the biosphere in the long run [2, 3].

The purpose of environmental remediation of former nuclear sites, including uranium mines, is to abate environmental contamination and ensure radiation safety [19, 20]. Current international safety standards have adopted 1 mSv per year, excluding the natural radiation background, as the maximum exposure tolerated to members of the public [1].

The main goal of remediation works is to confine residues and prevent reuse of radioactive materials (sand, gravel, stones) and contaminated mine waters in order to avoid enhanced radiation exposure of the population. It also aims to prevent external radiation, radionuclide leaching, and radon emanation from waste piles. Using the case of Urgeiriça mine as an illustration, the high radioactive content of milling tailings accumulated in Barragem Velha originated an ambient radiation dose rate on top of waste pile of 7.5 μGy/h, which would give an exposure of about 32 mSv/y or higher if people settle on it [2]. The multilayer cover placed over the waste pile reduced the external dose rate to the background level and also prevents radon exhalation and leachates to be formed and disperse from the waste pile into the environment.

4 Monitoring Occupational Radiation Exposure of Workers and Exposure of the Public

Uranium miners from the Urgeiriça mine and other uranium mines exploited in the past by the “Junta de Energia Nuclear” and later by the “Empresa Nacional de Uranio”, were considered as exposed workers (workers exposed to ionizing radiation from the radioactive ore) and individual dosimetry was provided to assess the radiation doses received [21]. Due to the working conditions existing at that time, external radiation doses alone may have exceeded the present dose limits, and dust and radon inhalation were probably poorly controlled. In several countries with similar uranium mining activities, epidemiological studies were carried out on cohorts of uranium miners which concluded that occupational exposure was the cause for high rates of lung cancer amongst miners [22]. Based on these lessons, the working conditions in uranium mines around the world are greatly improved. At the present, better protective measures and dose limitations are implemented and the exposure of miners dropped to satisfactory levels according to current safety standards [23, 24].

Current international safety standards have adopted 20 mSv per year, excluding the natural radiation background, as the maximum exposure tolerated to exposed workers [1]. Workers are classified as “exposed workers” if the implementation of economic, medical or other activities involving radiation, and deemed necessary and justified, cannot succeed without some degree of exposure above the dose limit for the members of the public. In this case efforts must be done to reduce exposure to the minimum (dose limitation), and workers must be enrolled in a radiation protection programme, including individual dosimetry monitoring and periodic medical surveillance [1].

Currently, there is no uranium mining in Portugal. Workers participating in the remediation works of old uranium and other mine sites cannot be classified as uranium miners and it is highly unlikely that they could be exposed to radiation at the same dose levels as in past uranium mining. These workers are involved in tasks such as removal of mining and milling waste piles, removal of contaminated top soil, truck loading and unloading of wastes, waste transportation, cover of uranium waste piles with non-contaminated soil, installation and maintenance of mine water treatment stations, including the removal of radioactive sludge from water treatment. These operations require, for example, the presence of workers on the top of waste piles, where radiation dose largely exceeds the natural radiation background. Furthermore, waste removal suspends dust into the atmosphere and releases radon from the waste piles that may be swallowed and inhaled by workers. Therefore, there is a radiation exposure hazard associated to environmental remediation and the assessment of exposure and radiation doses shall be performed for such workers. The assessment of radiation exposure must take in consideration the external radiation dose, dust inhalation, radon inhalation and, if applicable, ingestion of radionuclides with local foods and water. The duration of workers’ appointment is critical to determine the total radiation exposure (Figs. 1 and 2).

The radiation dose limits applicable to workers involved in environmental remediation works and site cleanup and decommissioning are, in principle, the same as applied to members of the public, 1 mSv per year (UE Directive 59/2013; Decree Law nº 222/2008). The eventual classification of environmental remediation workers as “exposed workers”, with toleration for a higher dose limit, requires prior radiological characterization of radiological hazards and classification of work posts, and thus a thorough assessment of exposure risks. Classification as “exposed workers” should only occur if it is demonstrated that after optimization of radiation protection, the work cannot be carried out under exposures up to 1 mSv/year. In this case, remediation workers can be classified as exposed workers and shall be enrolled in a radiation protection programme, including individual dose monitoring and medical surveillance provided by the employer. Desirably, workers should be provided with individual dosimeters (thermo luminescent dosimeters TLD, or other) for monitoring the whole body external dose, and the monitoring of exposure through inhalation should be performed for radon gas and for inhalable dust with

Fig. 1 Recontouring the uranium milling waste pile of Urgeiriça (Barragem Velha) and compacting the soil layers of the cover

Fig. 2 Removal and transport of uranium milling waste from the old mine and milling site of Forte Velho, Guarda

appropriate devices. Furthermore, according to radiation protection laws in EU and UN international safety standards applicable, workers must be informed of doses received and the individual doses must be communicated to the national Dose Registry data base to allow for exposure control (Decree Law nº. 222/2008).

Environmental legislation requires that an environmental impact assessment (EIA) of planned remediation works shall be done, but a radiological environmental impact assessment (REIA) should also be done according to international safety standards [24, 25]. Radiation exposure of the most exposed members of the public (i.e., local population) shall be monitored through an appropriate and approved site monitoring programme. On the basis of existing data from the radiological surveillance of old uranium regions and radioactivity in waste materials, such as Forte Velho (Guarda), Cunha Baixa (Mangualde), Urgeiriça (Nelas), Bica (Sabugal) with milling wastes with high radioactivity, it could be foreseen that environmental remediation works involve radiation exposure hazards to the workers and to the public.

One shall keep in mind that the initiative and approved programme for clean-up of old mine sites and environmental remediation is intended for solving environmental hazards and radiation risks inherited from past industrial activities. Nonetheless, current regulations and dose limits apply to the workers engaged in these works. Furthermore, during such remediation works all measures shall be implemented to reduce also the exposure of the public to radioactive materials, such as, for example, dust control to minimize re suspension of radioactive materials and management of contaminated mine water in order to prevent radioactive contamination of water lines.

Radiation exposure, and in particular dose limits and monitoring procedures, are today tightly regulated in comparison with the years of past uranium and radium mining. The remediation of the hazardous and radioactive mining and milling waste from uranium industry requires implementation of waste management and water treatment procedures. The safety of environmental and radiological impact of remediation works must be assessed and radiation safety of workers engaged in such activities, as well as the safety of the public, must be ensured according to the EU Directive 59/2013 now entered into force.

5 Conclusions

In Portugal the environmental remediation of old mine sites was approved to reduce environmental impacts, including radioactive contamination originated by uranium wastes and to protect the population from radiation exposure. A work plan (Director Plan) for the remediation work was approved and it has been implemented since then. Technical and engineering measures, equipment, and funding have been available to clean-up these sites and isolate and confine radioactive waste, and substantive progress in environmental remediation has been achieved.

However, although aiming to manage uranium mining waste legacy and to achieve noble objectives such as radiation safety of the population, the environmental remediation works are not out of the scope of EU Directive and are not exempt of applying current radiation safety standards. Radiation monitoring is needed also during the remediation works and protective measures must be implemented in order to ensure radiation safety of the workers and the public.

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Occupational Hygiene in Slave Work as a Potential Indicator for Typifying the Neo-Slavery

Gairo Garreto, João S. Baptista, Antônia Mota and A. Torres Marques

Abstract Until the end of the 19th-century, the Brazilian economy was dependent on slaves' work, particularly in rural areas. However, despite all international conventions and technological development that can replace advantageously human labour, slave work persists not only in Brazil but also in the most unsuspected places all over the world. This chapter aims to obtain, through a review of descriptive historical studies, a framework of the environmental conditions in which slaves performed their work and its implications in cases of accident or occupational disease. Electronic databases searched were Science Direct, Scopus, Web of Science, Criminal Justice, Ebsco, and Business Source Complete. Original historical documents were selected for their description of the rural work of slaves in colonial and imperial Brazil. Occupational hygiene, and environmental and climate conditions were compared with the neo-slaved worker´s conditions. The analysed studies pointed to the existence of diverse environmental conditions with similar exposure typologies among the slaves and neo-slaves across Brazil, even in distinct agricultural activities.

Keywords Occupational hygiene · Slavery · Neo-slavery · Brazil

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1 Introduction

Throughout all its colonial and imperial history, Brazil's economy was mostly based on agriculture, relying on the labour of the captive population [1].

During this period, the slaves would perform most of their tasks, like deforestation, excavations, plantations, weeding and harvest, using manual tools only, like axes and sickles. Even the machines in use on those times were Human or animal-powered [2].

Until the year 1888, when slavery in Brazil was abolished [1], the captive workers were labour and an asset, simultaneously [3]. Therefore, to ensure the return of their investment, this labour was forced to work for long periods, poor work conditions and low quality, usually insufficient meals. These are very precarious conditions for good health and safety [4–6]. However, these poor working conditions and the forced long hours of labour are still a reality at the beginning of the 21st-century.

Working conditions, similar to slavery, still exist in many countries [7]. The International Labour Organization (ILO), a United Nations (UN) agency, estimates in 40 million the number of people subject to slave work around the world [8].

At this moment, most governments reject neo-slave work, agreeing with ILO definition of neo-slavery and signing international treaties as the "Declaration on Fundamental Principles and Rights at Work", grounded in ILO regulations (conventions 29, 87, 98, 105, 138 and 182). However, neo-slaves exist and keep daily suffering accidents or developing occupational diseases without any control of Occupational Health and Safety (OHS), mainly due to the clandestine nature of their work.

According to the Brazilian Law (*Lei Nº.* 10,803/2003), there are four aggravating factors for neo-slavery that lead to the characterization of the neo-slave condition: (i) being subjected to forced labour; (ii) being subjected to long working hours; (iii) being subjected to poor working conditions; (iv) movement restrictions, by any means, due to debt towards the employer or representative. From these four characteristics, the poor working conditions and the long working hours are directly associated with the OHS conditions. Those conditions are described in the Brazilian Health and Safety Regulation as the minimally required work conditions. However, for this same reason, those conditions are not considered a crime but only as an infraction punishable with a simple fine. Therefore, in many of these situations, the penal code is not applied, but instead, the general labour laws are used. Given these conditions, the "employers" that use neo-slave labour can escape the expected penalties for these situations [9].

Nevertheless, the absence of technical and scientific support that could be used as a comparison parameter between slave work conditions at the times of legal slavery and the present neo-slavery allows, as mentioned, a legal framework for this practice, being seen as a simple violation of labour rules.

Even though there are several articles about slavery, they do not approach the problem from an OSH perspective. For that reason, this work is necessary for the better understanding of the OHS work conditions of the slave labour in Brazil, when it was legal. With that knowledge, it is expected to produce a better distinction between neo-slavery and simple violation of labour legal framework. This work should also contribute to unveil indications and methodologies for approaching and identifying neo-slave work, where this practice still exists.

2 Materials and Methods

This study was designed as a Systematic Review based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [10]. Descriptive studies that reported the rural working conditions of slaves in the imperial and colonial Brazil were selected. The following databases were searched: Science Direct, SCOPUS, Web of Science, Criminal Justice, Ebsco, Business Source Complete, starting in 2014. The same keywords combinations were used: slavery and work. No language filter was used, duplicated records were deleted.

Relevant articles were selected from titles and abstracts. Papers that didn't describe the environmental conditions of the practical activities executed by slaves were excluded. The inclusion criteria used was: (1) direct description of the theme of this study, (2) related to Brazilian slavery in the 19th-century and (3) recognised as a reliable source. After a first analysis of the complete studies, only the articles that allowed the extraction of relevant information within a patterned form (comprehensive reference, the region of the country, climate and occupational hygiene conditions) were included.

The bibliographic references of the selected articles were analysed and lead to a collection of data from several theses, dissertations, books and rare books (original publications dated from the 18th and 19th centuries).

The historical data found was compared with the data related to the poor, free workers of the same period, so it was possible to extract the normal exposure situations of the captive workers only.

Historical data were also analysed for similar situations in the light of current knowledge, in order to obtain an approximate quantification for the proven repeated exposure of 19th-century slaves to some agents. Finally, the dynamic of exposure to contaminants, considering the climatological conditions and occupational hygiene of those times, is presented.

3 Results

The searches in the six databases returned 36.355 records, from which five [4, 11–14] were selected for reading the full article after applying the inclusion criteria. The time frame of the search (2014–2018) excluded 28.498 items from the initial search, and 4.312 more were removed after using the requirement of having to be published in scientific journals. At last, 3.444 works were excluded for being out of the subject and 92 more after reading the abstract for not having the relevant descriptions necessary for this work. Remained the five initially included, which had indications of the descriptive characteristics in their abstracts. Besides those, 19 works were selected from the references of the previous ones. After the full analysis of those works, 16 were included in the systematic review: five articles, three books and eight rare books (Table 1).

Table 1 presents the weather, and occupational hygiene conditions to which slaves were subjected by geographic region. It is evident that exposure to a severe work environment was common, leaving the slaves in a situation of high vulnerability.

Regarding the occupational hygiene conditions, the descriptions related to the chemical agents contaminating the respiratory airways, such as dust, vapours, gases and fumes, were highlighted. These descriptions are indicative of the high concentrations of these pollutants at such high levels that they could cause more suffering than the daily difficulties of forced labour.

Table 1 Climatology e occupation hygiene

#	Description's geographic area	Environmental working conditions	
		Climate	Occupational hygiene
[1]	Southeast Brazil	Under severe weather, cold, rain and sun	Dust and humidity
[2]	All of Brazil	Varied climate	
[3]	All of Brazil	Under severe weather	
[4]	São Paulo	Under heat, humidity and cold	Stagnant water and mosquitoes' vectors
[11]	Maranhão		Venomous animals
[12]	All of Brazil	Coastal regions rarely below the 25 °C	
[15]	Southeast Brazil	Heat and rain	Toxic vapours
[13]	Minas Gerais	Under severe weather, cold, rain and sun	Dust and humidity
[16]	Maranhão	Heat and rain	
[17]	All of Brazil	Hot and humid with much rain	Venomous animals
[18]	Maranhão	Hot and humid with much rain3	
[32]	Maranhão	Hot and humid	
[19]	Maranhão	Hot and humid	
[21]	Bahia	Hot and humid	Humidity, furnace heat, gases and smokes
[14]	Pará	Much rain in the first months of the year	
[33]	Maranhão	Hot and rainy, with 4–6 months of drought per year	

Exposure to potentially disease-carrying animals and insects was considered intrinsic to rural work. The description in the historical reports was that the exposure was very high, particularly in deforestation of virgin forests and sowing in the rainy season.

4 Discussion

4.1 Occupational Hygiene in Slave Work

This review gathered information about the climate conditions and occupational hygiene of the slave workers in colonial and imperial Brazil from articles and other sources as original statements. A considerable amount of the data was collected in rare books (Table 1), which were consistently found in the references of the scientific articles found through the databases from the period when slavery was legal in Brazil.

The included 16 studies show objective descriptions that were possible to categorise into Table 1. However, none of these studies had as primary objective to study, analyse or describe aspects related to the OSH. Despite this, the included studies show good descriptions even they are complementary to the primary purpose of each of these works.

The following paragraphs use data extraction from the included studies, even if some works show more apparent descriptive data, with less deepen paragraphs or phrases, all contributing to the general description and reinforcing data from other sources with more detailed and descriptive accuracy. Some rare publications [2, 15] that, due to its technical and scientific character, were directed to the economic needs of the landowners of that period. Detailed data on slave labour activities and even procedures to prevent illness and death so that maximum economic profit could be obtained with the investment made, were described.

Books from the 19th-century [15–19] report hot climate conditions with heavy rain. Even existing several types of climate in Brazil, the main plantations were concentrated in tropical regions. Those books also describe how the weather was interpreted by European immigrants.

The book of *do Alferes* (1878) mention the risk of death of slaves that sleep in the warehouses where rice was stored due to the vapours released by the grains, it is a fascinating report of occupational hygiene. The present version of these warehouses are the grain silos, which continue to represent the same risk already reported in the 19th-century. These ‘deadly vapours’ are toxic and suffocating gases, mainly nitrogen dioxide (NO_2) and carbon dioxide (CO_2), emanated by the grains after the harvest and can reach high concentrations in low ventilation environments [20].

Machines are also described as essential and reported in several works [2, 11, 15, 21, 22]. There were devices for all sorts of purposes, as ginning cotton, sugar processing and grinding grain. Most of them were powered by animals or humans but, some used hydraulic energy and, later a new form of force was used with the introduction of vapour machines.

The use of manual tools, animal, hydraulic, and vapour power devices for the sugarcane mills by the enterprises is carefully detailed in the book of Schwartz (1988). This author also described in detail each step of the sugar production process with these devices in such way that it was possible to extract elements regarding the occupational hygiene conditions as the presence of smokes, vapours, gases, furnaces and moisture that the slaves were exposed to in their work environment.

In the 19th-century, sugarcane bagasse was used as fuel for the most different purposes, from ceramics to steam production, due to its availability. However, it was in the sugar-producing devices that this energy source was more intensively used. However, although the smoke produced in this operation be less damaging then that of cane leaf [23], this exposure was very intense e and, consequently, more damaging, in particular during the periods of sugar production, where the working day never took less than 14 h [21].

By other side, cotton-ginning devices produced big amounts of cotton fibres. These vegetable clouds of dust were scattered in the workplace and inhaled by the slaves. The occupational exposure to these dust, in its breathable fraction, is associated with a clear increase in respiratory disorders among directly exposed slaves [24, 25].

4.2 Occupational Hygiene in Neo-Slave Work

Currently, for the users of neo-slave labour, the initial investment is substantially lower since it is limited to transporting the worker to the farm and to the commission paid to the allurer [26]. Thus, the working environmental conditions observed in the slave work of the 19th-century are replicated similarly, or in some cases, worsened, in the neo-slave work of the 21st-century.

As an example, leaves' burning and sugarcane manual cutting still being performed in the same way and with the same kind of occupational exposure as the slave workers in the 19th-century. Leaves' burning is particularly damaging in that the fumes generated are almost entirely ($\sim$96% in weight) within the breathable fraction (aerodynamic diameter <4 μm) [23].

Controlled forest fires to create new agricultural fields continue to be often carried out by neo-slaves, using the same 19th-century methods. However, the exposure to the smoke generated by wood burning is less damaging, concerning its breathable fraction (average of 1.3% by volume), when compared to the smoke generated by the cane leaf smoke. Even so, there are high average values of particulate material ($PM_{2,5}$) and carbon monoxide (CO) in the breathable air [27, 28].

Unprotected exposure to cotton dust is usual in most of the cotton-ginning operations in the small agroindustry in developing countries in the 21st-century. They use roller mills [29] with operation principles similar to the devices used in the 19th-century Brazilian cotton farms. In average, the operators of these devices are exposed to concentration ranging from 2 to 5 mg/m^3 of inhalable cotton fibre dust [29–31], surpassing tens of times the tolerance limit of 0.2 mg/m^3 suggested by American Conference of Governmental Industrial Hygienists (ACGIH) and Occupational Health and Safety Assessment Series (OSHAS).

5 Conclusions

This research presents as strengths an extensive search in the electronic databases and also directly in rare books, where it was possible to identify detailed and concise descriptions about slave work. The general perception of how the occupational working conditions were during the legal slavery period permits a comparison with the current occupational hygiene conditions relatively to neo-slavery.

In their daily work, slaves were particularly vulnerable to climatic, physical, chemical, and biological occupational agents. These agents had diverse origins, such as controlled fires, vegetable dust or animal vectors. As a consequence, the occurrence of diseases of the most different types was frequent in the plantations.

The working conditions analysed were similar in all Brazilian regions, as can be observed in Table 1, through the geographical origin of the descriptions. It was also possible to demonstrate the diversity of contaminants to which slaves were exposed in 19th-century Brazil.

This book chapter presents evidence that both exposures to bad weather and occupational hygiene conditions occur very similarly among captive 19th-century workers and many rural workers in the 21st-century.

This similarity of the working conditions between the two reported periods makes the hypothesis of comparison between slave, and neo-slave work may be a reality in the next future to clarify situations of neo-slavery. However, the distinction between simple violations of the labor legal framework and human rights violations by the crime of neo-slavery still being not so simple. Therefore, it is hoped that this work gives a contribution to help to distinguish between these two conditions.

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Evaluation of Whole-Body Vibration in Automobile on Routine Travel—A Case Study

Ahmet Meram and Mohammad Shahriari

Abstract This paper presents the investigation on the ride comfort of automobile travelling on city roads with a different profile and roughness. The aim of the study was to evaluate and assess the vibration severity on the automobiles travelling in a highway in Konya city according to the data presented in International Standard ISO 2631-1. To reach to this aim, unweighted root mean square value of accelerations in 1/3 octave band at the driver's seat in routine travel speeds in the vertical, lateral and transverse directions have been measured by a sound & vibration hand-held Analyzer. The measurements were conducted in a road with 24 km length during 25 min. The road surface is mainly smooth categorized with a series of bumps, roughness and holes. To evaluate and assess the whole-body vibration severity the achieved data were classified according to three types of road surface characteristics. Measurements of vibration in a long path have shown the vibration severity in the vertical direction was higher than two other directions and acceleration varies between 0.3 and 0.8 ms^{-2}. According to recommendations given in ISO 2631-1, the acceleration 0.8 ms^{-2} was in uncomfortable ranges. Meanwhile, the dominating acceleration in vertical direction appeared in frequencies lower than 12 Hz. Since the human body is so sensitive to vibrations less than 12 Hz, to lessen the adverse effect of high acceleration it may be recommended to repair the uneven surfaces decrease the bumpy surfaces.

Keywords Ride comfort · Whole body vibration · Bumpy road

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1 Introduction

Expose to vibration has an adverse effect on comfort, performance, and health of driver and passengers in automobiles [1]. The reaction of the human body to vibration may be classified under three categories: physical, physiological and psychological. Physical reaction patterns in the transfer of vibrations from one body part to any other part. Physiological reaction is seen as blood pressure and heart rate changes, and irritation and psychological reaction such as loss of patience, attention loss [2]. A study by Ishitake et al. [3] proved that whole body vibration (WBV) exposure disrupts the normal rhythm of gastric motility. Jiao et al. [4] found a positive relationship between the WBV exposure and change in heart rate and four symptoms of fatigue such as lack of spirit, physical tiredness, desire to lie down and stiff shoulders.

The vibration in the roads is generated by rough and bumpy surfaces in forms of shocks and by unevenness of the road surface as continuous vibration. Exposure to both shapes of vibration has negative effects on the automobile driver and passenger's health. The study of Smith et al. [5] showed that there is a correlation between and the general discomfort of the driver and passengers and the root mean square (r.m.s.) value of acceleration. Both the frequency and amplitude of mechanical shocks affect the human body. Vibrations up to 12 Hz affect all of the human organs and those above 12 Hz have local effects. Low-frequency (4–6 Hz) vibrations, such as those generated when tires rolling over a rough road, can resonate the body. Exposure to vibration for one hour in the seated position may cause muscle fatigue and make the driver and passenger more sensitive to back injury [6]. Huston and Zhao [7] analyzed the effect of frequency and amplitude of mechanical shocks on the comfort of the human body in the seated position. Also, Jonsson and Johansson [8] investigated the effects of vehicle speeds and road surfaces (smooth and rough) on the comfort of occupants by considering the vibration accelerations.

Although Els [9] proved that all the four methods namely ISO 2631-1, BS 6841, AAP and VDI 2057 can be successfully used to determine ride comfort of vehicle, to evaluate the human responses to whole-body vibration two standards; International Standard ISO 2631-1 [10] and the British Standard 6841 [11] are mainly considered. The BS 6841 considers a frequency range of 0.5–80 Hz and suggests measuring four axes of vibration on the seat. Also, to assess the vibration severity combines the acceleration values. The ISO 2631-1 recommends measuring the vibration in the three translational axes on the seat pan and using the greatest vibration to evaluate the vibration severity [12, 13]. Table 1 gives the recommended comfort/discomfort ranges of acceleration by ISO 2631-1.

This study aims to find out what accelerations are acting at the driver's seat in a highway in Konya city. This highway as shown in Fig. 1a connects two university compasses (Necmettin Erbakan and Selcuk universities) and two large public hospitals (Meram and Selcuk medicine). Hundreds of thousand automobiles are moving in this road daily. Motivated by this fact, this study is undertaken to measure the lateral, transverse and vertical directions are acting on the driver's seat

Table 1 The comfort/discomfort ranges of acceleration (ISO 2631-1)

Acceleration range (m/s^2)	Acceptability
Less than 0.315	Not uncomfortable
0.315–0.63	A little uncomfortable
0.5–1	Fairly uncomfortable
0.8–1.6	Uncomfortable
1.25–2.5	Very uncomfortable
Greater than 2	Extremely uncomfortable

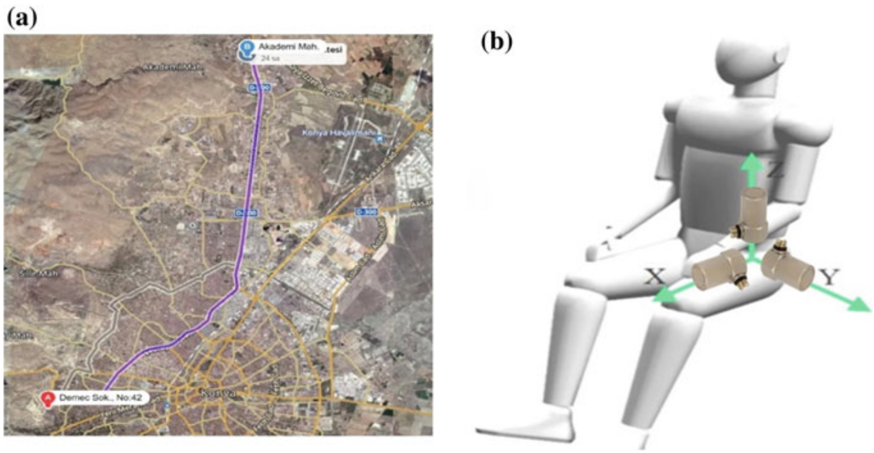

Fig. 1 **a** Test site, **b** Schematic of three-axis vibration of a driver

in routine travel speeds. Then, evaluate the ride comfort by considering the acceleration criteria recommended in International standard ISO 2631-1.

2 Methodology

To evaluate and assess the vibration level in the path shown in Fig. 1a, a series of measurements was conducted. The test site is located between Necmettin Erbakan university campus and Selcuk university campus in the city of Konya (Turkey). The length of the path is 24 km and takes 20–25 min in routine riding speed. The road surface is mainly smooth categorized with a series of bumps, roughness and holes. To measure the vibration Brüel & Kjær sound & vibration hand-held analyzer types 2250 in conjunction with miniature accelerometer type 4397-A were used. This sensor measures the frequency unweighted r.m.s accelerations in 1/3 octave band. The accelerometer is mounted on the frame of driver's seat using a permanent

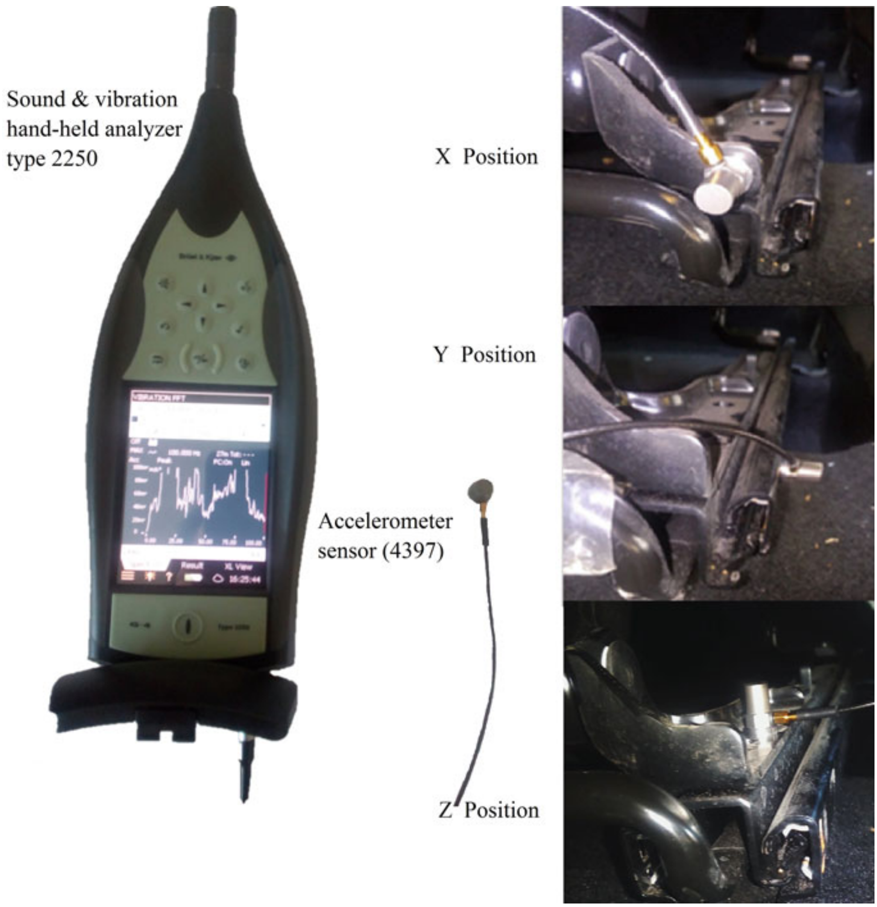

Fig. 2 Sound & vibration hand-held analyzer type 2250 and accelerometer type 4397-A mounted in lateral (x), transverse (y) and vertical (z) positions

magnet as shown in Fig. 2. The rigid frame of the driver's seat transfers about whole of the vibration to the driver's body. The measured vibration data from the rigid frame under the driver's seat is approximately equal to vibrations have been sensed by driver. It should be emphasized that usually, a tri-axial accelerometer mounted on a rubber pad is used to determine vibrations affecting the whole body in passenger vehicles. However, this study is limited to measuring the vibration by the miniature accelerometer. In further study the tri-axial accelerometer will be used to assess the vibration.

Miniature accelerometer type 4397-A with weight 2.4 g includes internal electronics CCLD and measures in frequency range 1–25 kHz, and sensitivity 1mv/ms^{-2}. Since the accelerometer type 4397-A measures only on one direction, to obtain the acceleration values in lateral (x) and transverse (y), vertical (z) directions the measurements were conducted three times by changing the position of the sensor at the unique condition. Schematic of three-axis vibration of a driver, in sitting position, is shown in Fig. 1b. Fiat Egea 1.3 multijet 95 hp urban sedan model (2017) a passenger car with the suspension system in good condition was used to measure the road inducing acceleration values. It is a four-door sedan with the empty weight of 1205 kg with 16-inch rims. For FFT analysis software BZ-7230 was employed. The analyzer automatically calculates the root mean square of each signal. Because in frequencies over 100 Hz the human body becomes less sensitive to vibrations, the frequency range of 0–100 Hz was selected for measurement. The record duration was selected for 60 s. Totally 73 acceleration curves in frequency unweighted spectrum were obtained in 1/3 octave band. Most of the data were like each other for lateral, transverse and vertical directions. In order to evaluate the vibration distribution in the test site, the obtained curves were classified in three road surface categories. The selected data to evaluate and to assess are illustrated in the results and discussion section.

3 Results and Discussion

The acceleration data in lateral, transverse and vertical directions on the driver's seat was measured. The data were saved every one minute and the frequency span of FFT analysis was 100 Hz. The measured data were classified according to three kinds of road surfaces. The characteristics of the road surfaces in the test site can be summarized in three categories: (1) road consisting of a series of bumps, (2) poorly kept road consisting roughness with small holes and (3) road with the smooth surface. The measurements are analyzed according to the recommendations in International standard ISO 2631-1. Frequency unweighted root mean square (r.m.s.) of accelerations measured in lateral, transverse and vertical directions and the surface of a bumpy road are shown in Fig. 3a–d, respectively. It is observed that r.m.s. value in the vertical direction is greater than values in two other directions.

According to data presented in Table 1 the acceleration in the transverse direction is in a little uncomfortable range and the acceleration values in lateral and vertical directions are in fairly uncomfortable range. The dominating acceleration in vertical direction happened in 11 Hz. With attention to that vibrations up to 12 Hz affect all of the human organs, driving in this situation may have an adverse effect on the health of driver and passengers. In lateral direction maximum acceleration (0.64 ms^{-2}) occurs around 22 Hz. This frequency is near to the resonance of parts in the head. The dominating acceleration in transverse direction happens in 8 Hz. Although the severity of vibration in direction is lighter than others it may combine with vibration in the vertical direction. Figure 4a–c, and d show the frequency unweighted r.m.s. values of acceleration in the lateral, transverse and vertical direction and the smooth surface of the road, respectively. The allowable speed in this road is 82 km/h. The severity of the acceleration in three directions is in not uncomfortable range according to the data in Table 1.

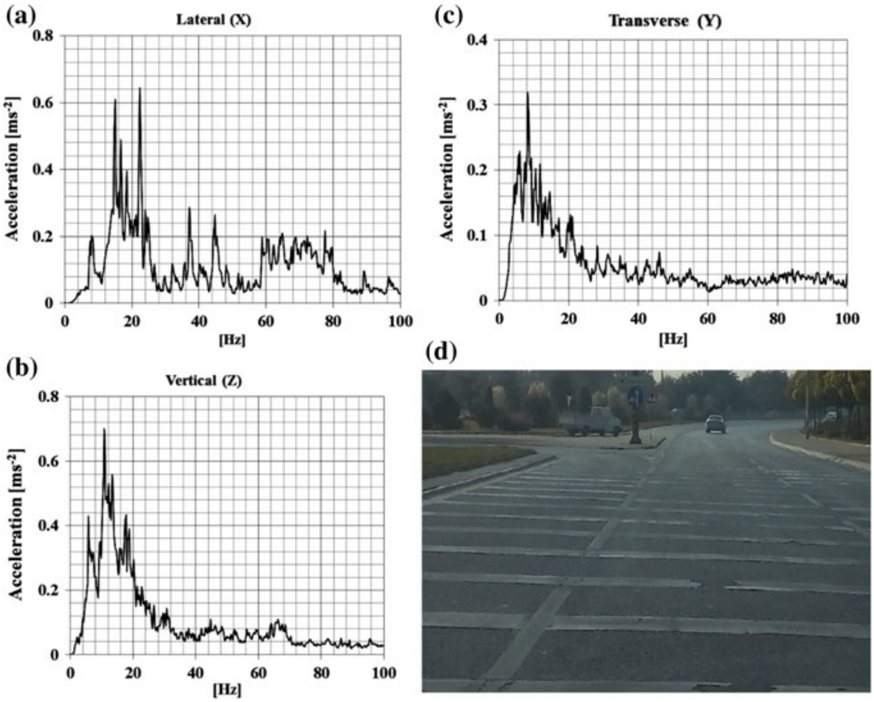

Fig. 3 Vibration data measured while driving on the bumpy road at 60 km/h: **a** lateral direction **b** transverse direction **c** vertical direction **d** surface of road consisting of a series of bumps

Figure 5a–c, and d illustrate the frequency unweighted r.m.s. values of acceleration in lateral, transverse, vertical directions and the surface of road with poorly kept consisting roughness with small holes while driving at 60 km/h speed, respectively. The maximum acceleration in lateral direction about 0.6 ms^{-2} happens in 20 Hz which is in a fairly uncomfortable range. In transverse direction, the acceleration level is in comfortable range. The value of dominating acceleration in the vertical direction on the uneven road is near to 0.8 ms^{-2}. Although the speed of the automobile is in reasonable range, according to data given in Table 1, this acceleration severity remains in uncomfortable range.

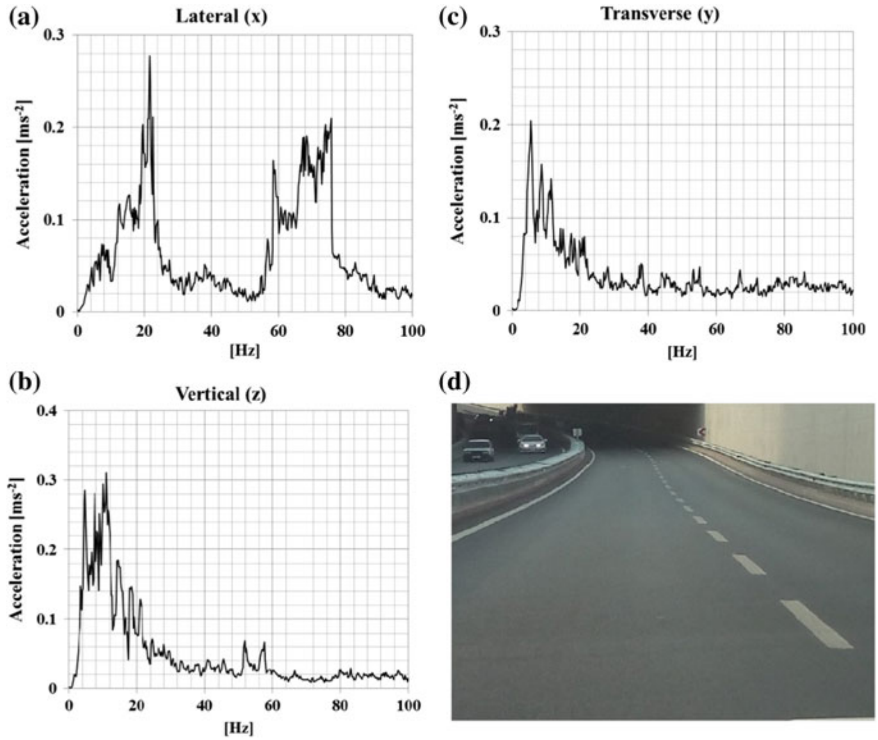

Fig. 4 Vibration data measured while driving on the road with excellent surface at 82 km/h: **a** lateral direction **b** transverse direction **c** vertical direction **d** road with smooth surface

4 Conclusions

This paper reported the measurements results of vibration induced by the road surface on a path in Konya city. The acceleration values in lateral, transverse and vertical directions under the driver's seat were measured using hand-held vibration analyzer in conjunction with a miniature accelerometer. The acceleration data were obtained in the frequency spectrum. In order to evaluate and assess the whole-body vibration severity, the achieved data were classified according to three kinds of road surface characteristics. Measurements of vibration in a long path have shown the vibration severity in the vertical direction was higher than two other directions and acceleration varies between 0.3 and 0.8 ms^{-2}. According to recommendations given in ISO 2631-1, the acceleration 0.8 ms^{-2} was in uncomfortable ranges. Meanwhile, the dominating acceleration in vertical direction appeared in frequencies lower than 12 Hz. Since the human body is so sensitive to vibrations less than 12 Hz, in order to lessen the adverse effect of high acceleration it may be recommended to repair the uneven surfaces decrease the bumpy surfaces.

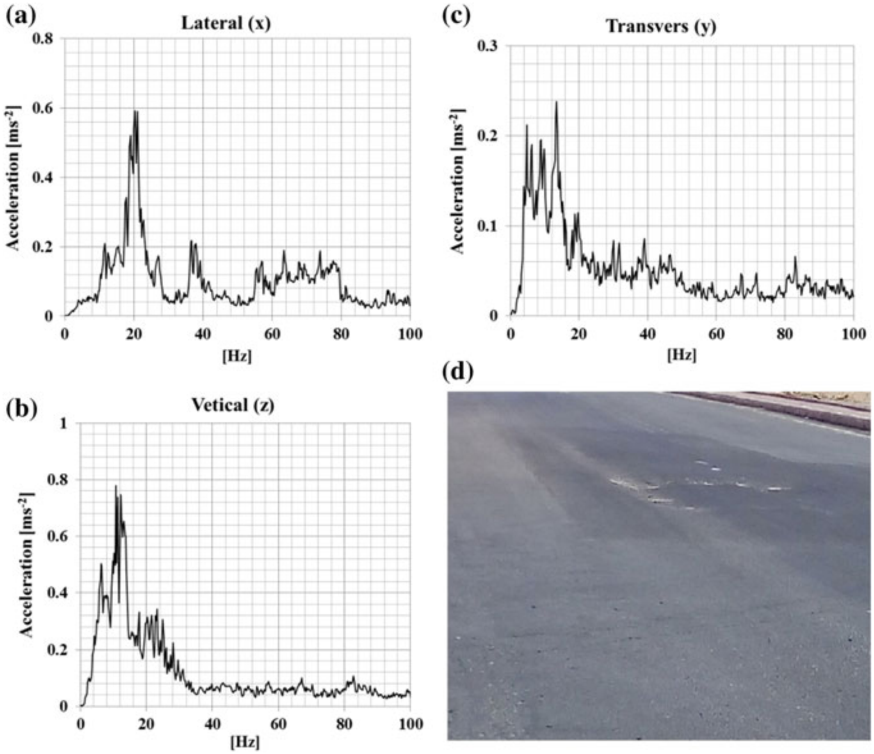

Fig. 5 Vibration data measured while driving on the road with poorly kept consisting roughness with small holes at 60 km/h: **a** lateral direction **b** transverse direction **c** vertical direction **d** the road with poorly kept consisting roughness with small holes

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Barbecue Grill Workers Occupational Exposure to Particulate-Bound Polycyclic Aromatic Hydrocarbons

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Abstract During a regular working day, grill workers are exposed to the emissions of charcoal-fired cooking activities, which include polycyclic aromatic hydrocarbons (PAHs) that are among the most health relevant compounds. Thus, in this work, the particulate matter at the breathing air zone of grill workers from a barbecue restaurant was sampled and the concentration of eighteen particulate-bound PAHs was determined by liquid chromatography with fluorescence and diode array detection. Median level of total PAHs (ΣPAHs) during 5 consecutive hours of exposure to barbecue fumes was 77.2 ng/m^3 (maximum values of 261 ng/m^3). Benzo(g,h,i)perylene, phenanthrene, and acenaphthylene were the most abundant compounds (82.7% of ΣPAHs). Levels of benzo(a)pyrene and total carcinogenic PAHs (naphthalene, benz(a)anthracene, benzo(b)fluoranthene, benzo(j)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, chrysene, and indeno(1,2,3-cd)pyrene) varied between 0.03–0.79 ng/m^3 and 2.10–36.7 ng/m^3, respectively. Grill worker's exposure to PAHs was well below the existent PAHs occupational threshold limit value of 200 μg/m^3 proposed by the American Conference of Governmental Industrial Hygienists for an 8-h of exposure to coal tar pitch volatiles. Some preventive measures such as adequate maintenance of barbecue venti-

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lation system, regular wash of workers exposed skin and the use of clean working clothes can contribute to reduce grill worker's occupational exposure to PAHs.

Keywords Occupational exposure · Grill workers · Polycyclic aromatic hydrocarbons

1 Introduction

Populations living in large urban centers face high work rates and the lifestyle and the dietary habits of people have been changing. As a consequence, the number of self-service and take-away restaurants has been significantly increasing over the last years. In Portugal, grilled foods are highly appreciated. Therefore, barbecue restaurants with take-away services bloomed in Oporto (Portugal) metropolitan area during the last years. Charcoal has been exhaustively used in Portuguese barbecue restaurants to grill food mostly due to its high energy content and stability. Charcoal is easy to transport and store inside restaurants and is easily ignited, extinguished, and reheated if needed. The combustion of charcoal at barbecue restaurants releases large amounts of air pollutants, including carbon monoxide, particulate matter, heavy metals and organic compounds, such as polycyclic aromatic hydrocarbons (PAHs), formaldehyde, and carbonyls [1–4].

PAHs are a large group of organic compounds formed during the incomplete combustion of organic matter. At barbecue restaurants, there are two major sources of PAHs: firstly, during the ignition step of biomass (charcoal, liquefied petroleum, gas, etc.) and secondly during food processing or cooking steps such as grilling, roasting, and barbecuing [1, 3]. PAHs are known for their recognised toxic, mutagenic and carcinogenic properties [1, 3, 5, 6]. The agency for toxic substances and disease registry reported that PAHs possess reproductive, developmental, hemato-, cardio-, neuro-, and immune-toxicities in both humans and laboratory animals [7]. A total of sixteen PAHs (naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benz(a)anthracene, chrysene, benz(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, dibenz(a,h) anthracene, benzo(g,h,i)perylene, and indeno(1,2,3-cd)pyrene) are included in the US EPA priority pollutants list [8]. Among those compounds, benzo(a)pyrene is classified as known carcinogen for humans [6], while naphthalene, benz(a)anthracene, benzo(b)fluoranthene, benzo(j)fluoranthene, benzo(k)fluoranthene, chrysene, and indeno(1,2,3-cd)pyrene are possible/probable carcinogens to humans [5, 6]. Dibenzo(a,l)pyrene and dibenz(a,h)anthracene are also regarded as probable carcinogens to humans [6, 9].

Grill workers are regularly exposed to the emissions released during charcoal-fired cooking activities. Data concerning occupational exposure to the emissions of charcoal at barbecue restaurants is limited [4, 10–15]. Thus, the present work aims to assess barbecue grill workers occupational exposure to particulate-bound PAHs released during charcoal-fired cooking activities.

2 Materials and Methods

2.1 Personal Air Sampling

In this work, a local barbecue restaurant situated in Vila Nova de Gaia city, Oporto district (North of Portugal) was considered. Non-smoking grill workers were invited to participate in the study, through a personal structured questionnaire [16]. The form allowed collecting biometric information of the workers (age, weight, height, etc.) but also data related with the number of years working as grill worker and tobacco smoking habits. Air sampling campaigns were performed according to the method NIOSH 5506 in the grill working area of the restaurant during five consecutive working days in June 2017 [17]. Grill working area was next to the take-away section of the restaurant in the costumers' main entrance. Personal air sampling campaigns started around 10 am with the ignition of the charcoal in the grill and finished around 3 pm in the end of the first working shift. Grill workers were invited to use personal constant flow samplers (Air Check 2000, 210-2002, SKC Ltd, United Kingdom) that were placed at the waist region in a position that could not interfere with their normal tasks. Air sampling device consisted in a three-piece filter cassette, a filter cassette holder, and a SKC respirable dust cyclone with a validated cut-point of 4 µm. Pumps were regularly calibrated at the air flow of 2.5 L/min. The inlet of the sampling air collector was positioned at the breathing zone of the worker. Particulate air samples were collected on polytetrafluoroethylene membrane filters with polymethylpentene support ring (2 µm porosity, 47 mm, SKC Ltd, United Kingdom). At the end of the work shift, filters were removed from the pump, weighed and stored in a freezer (−20 ºC). Overall, a total of five filters were collected for each grill worker. During the sampling campaign period, the mechanical ventilation system was turned on at the beginning of the day, being kept on during all working day. The air velocity of the barbecue hood was kept constant during all the sampling campaign. A researcher was always present at the restaurant to register the working routine of the workers and the mechanical ventilation system status.

2.2 Extraction and Chromatographic Analysis

Extraction and quantification of PAHs from PM_4 filters were done according to previously validated methodologies [18–20]. Briefly, 18 PAHs were extracted from

PM filters with 30 mL of acetonitrile by microwave assisted extraction under controlled conditions (20 min at 110 ºC with medium stirring). After extraction, extracts were evaporated to dryness and re-dissolved in 250 μL of acetonitrile for chromatographic analysis [18–20].

2.3 Data Treatment

Data analysis was performed with SPSS (IBM SPSS Statistica 20) and Statistica (v. 7, StatSoft Inc., USA) software. When the concentration of some PAH was below the limit of detection (LOD) of the method, the value of the respective LOD/$\sqrt{2}$ was used [21]. Concentrations of PM_4-bound PAHs were presented as median, percentile 25–75, and range. Median values were compared through non-parametric Mann-Whitney U test, since normal distribution was not observed. Statistical significance was defined as $p < 0.05$.

3 Results and Discussion

Concentrations of total PAHs (ΣPAHs) in the breathing air zone of barbecue grill workers during a regular work shift presented a median value of 77.2 ng/m^3 and ranged from 56.2 to 261 ng/m^3 (Table 1). Among the 18 compounds under study, phenanthrene, fluoranthene, pyrene, and benzo(g,h,i)perylene were detected in all the air samples, while naphthalene, fluorene, anthracene, benz(a)anthracene, benzo (b + j)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene were detected in 25–75% of the samples; acenaphthylene, acenaphthene, chrysene, and dibenzo(a,l)pyrene were not detected in the breathing air of grill workers. The most abundant PAHs in the breathing air of grill workers were benzo(g,h,i)perylene (50.8% of ΣPAHs), followed by phenanthrene (23.3%), and acenaphthylene (8.6%). Altogether these three compounds represented 82.7% of ΣPAHs (Fig. 1). Dibenz(a,h)anthracene and pyrene accounted with 5.4 and 4.6% of ΣPAHs, respectively. The remaining PAHs contributed with less than 2% for ΣPAHs.

The median concentration of carcinogenic PAHs ($\Sigma PAHs_{carc}$) in the breathing air zone of grill workers was 6.00 ng/m^3 (Fig. 2a), with values ranging between 2.10 and 38.7 ng/m^3. $\Sigma PAHs_{carc}$ represented 7.8% of ΣPAHs being dibenz(a,h) anthracene, benzo(b + j)fluoranthene, and naphthalene the compounds that contributed the most (Fig. 2b). The median concentration of benzo(a)pyrene, the PAH marker of exposure to carcinogenic PAHs [3], was 0.04 ng/m^3 (0.03–0.79 ng/m^3) and accounted with 1.3% for $\Sigma PAHs_{carc}$. Grill worker's exposure to PAHs was well below the existent PAHs occupational threshold limit value of 200 μg/m^3 proposed by the American Conference of Governmental Industrial Hygienists for an 8-h of exposure to coal tar pitch volatiles [19].

Table 1 Concentrations of PM_4-bound PAHs (median, percentiles 25–75, and range; ng/m^3) in the breathing air zone of barbecue-grill workers

PAHs	Median	P_{25}–P_{75}	Range
Naphthalene	0.16	0.16–1.84	0.16–3.74
Acenaphthylene	7.23[a]	–	–
Acenaphthene	0.49[a]	–	–
Fluorene	0.03	0.03–0.07	0.03–0.12
Phenanthrene	21.2	15.0–35.8	10.9–50.4
Anthracene	0.43	0.23–1.09	0.23–1.38
Fluoranthene	1.67	1.24–2.39	0.87–3.25
Pyrene	4.16	2.89–6.43	2.38–8.51
Benzo(a)anthracene	0.06	0.02–0.24	0.02–0.41
Chrysene	0.34[a]	–	–
Benzo(b + j)fluoranthene	0.65	0.65–1.29	0.65–2.18
Benzo(k)fluoranthene	0.08	0.06–0.33	0.06–0.71
Benzo(a)pyrene	0.04	0.03–0.40	0.03–0.79
Dibenzo(a,l)pyrene	0.28[a]	–	–
Dibenz(a,h)anthracene	2.50	0.48–17.2	0.48–32.6
Benzo(g,h,i)perylene	40.2	26.3–98.9	22.9–153
Indeno(1,2,3-cd)pyrene	0.07	0.07–0.72	0.07–1.64
ΣPAHs	77.2	62.6–169	56.2–261

[a]Compounds were not detected (LOD/$\sqrt{2}$ was used [21])

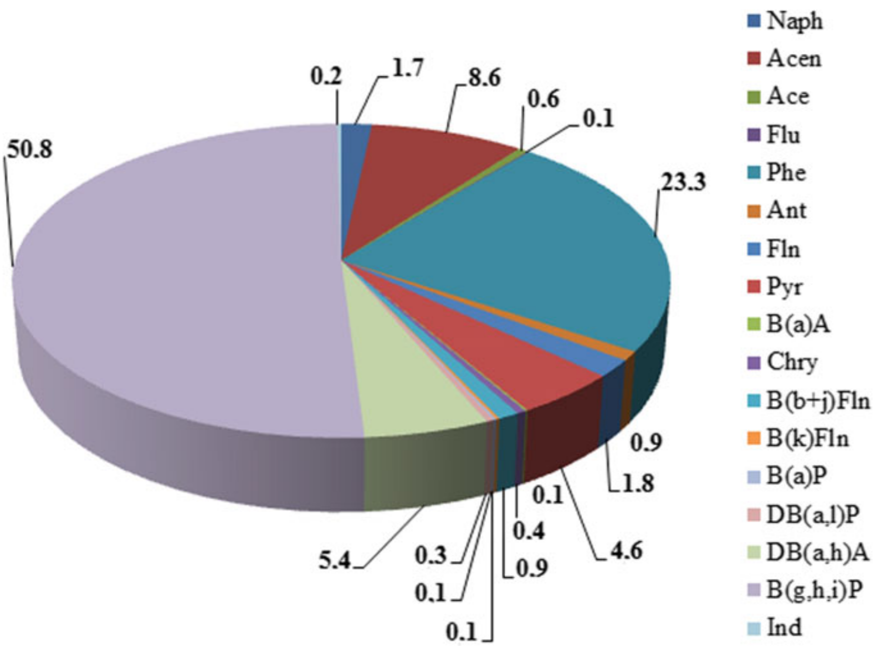

Fig. 1 Distribution of PAHs (%) in the breathing air zone of grill workers

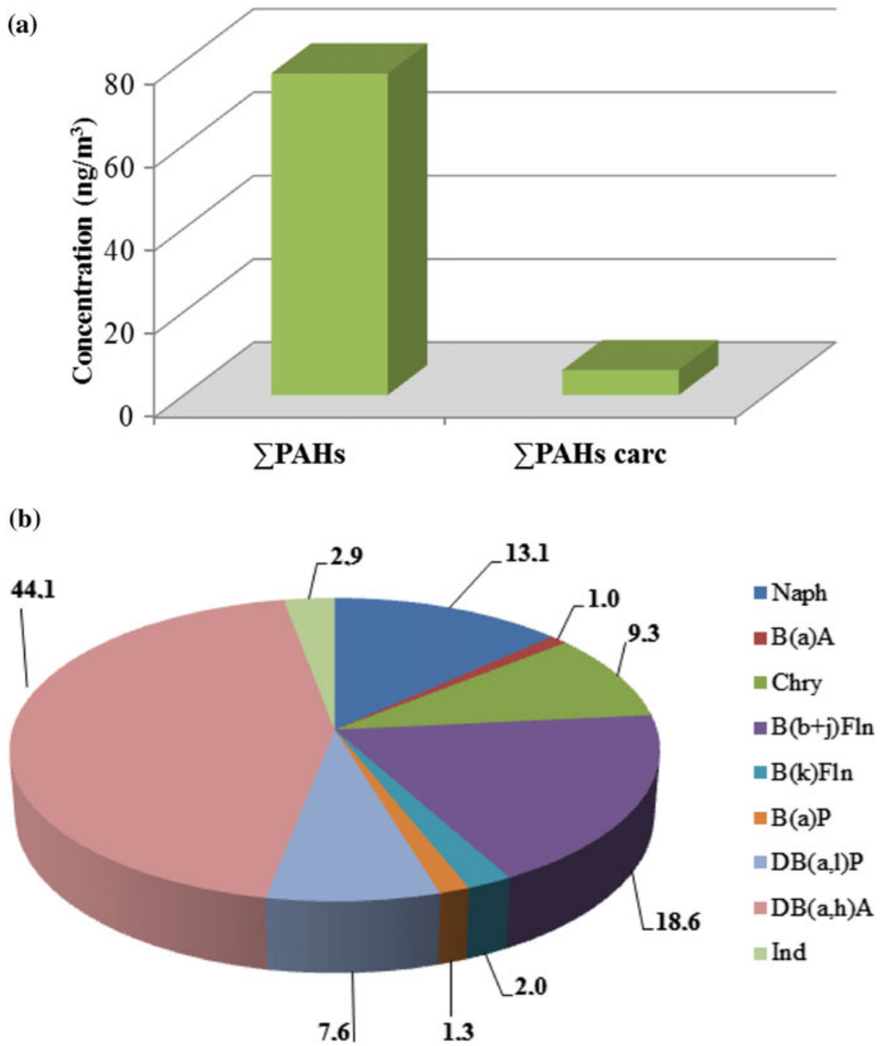

Fig. 2 Concentration (**a**) and distribution (**b**) of carcinogenic PAHs in the breathing air zone of grill workers

There are limited studies regarding grill worker's occupational exposure to charcoal-fired cooking activities [4, 10–15]. From those studies only two included the exposure to PAHs [12, 15]. To the knowledge of the authors no study was found regarding European grill workers. The concentrations of ΣPAHs (median 77.5 ng/m^3; Table 1) in the breathing air zone of Portuguese grill workers during five consecutive hours of a regular working day at a barbecue restaurant were well below than the levels reported for Chinese vendors of charcoal-broiled foods at night market (2276–2445 ng/m^3) [12]. However, levels were in close range with the concentrations of ΣPAHs reported in the barbecue fumes of Chinese outdoor barbecuing vendor stalls (50 ± 14 and 320 ± 265 ng/m^3 at a distance of 10 and 2 meters away from the vendor stall, respectively) [15]. More studies with a higher number of barbecue restaurants are needed to validate the obtained results.

Recently, Lao et al. [22] showed the importance of dermal absorption in the intake of PAHs from barbecue fumes. Those authors found a greater contribution of dermal, comparatively with inhalation, uptake of PAHs with low molecular weights in non-occupational exposed people. Based on these findings, some protective measures may be proposed for grill workers, who are occupationally exposed to barbecue fumes, namely: (i) avoid dermal contact by using protective clothes (hat and long-sleeved sweater) that reduce the skin area exposed to barbecue fumes; (ii) wash the exposed skin (face, neck, hands, and arms) several times a day, principally after the most intensive periods of work; (iii) clean regularly the used clothes to reduce the accumulation of pollutants; and (iv) keep the barbecue hood always working in good conditions. Morrison et al. [23] concluded that clothes continuously exposed to pollutants can contribute to increase the amount of dermal intake while clean clothes may reduce or even impede skin absorption.

4 Conclusions

This work characterized grill workers exposure to PM-bound PAHs during a regular work shift at a barbecue restaurant. The obtained data revealed that even with the use of mechanical ventilation system, workers were exposed to PAHs at levels that ranged between 56.2 and 261 ng/m^3 (median 77.2 ng/m^3), with 7.8% of ΣPAHs being carcinogenic compounds. Therefore, more studies regarding the occupational exposure of grill workers to PAHs are needed to better characterize the regular exposure of these workers and to estimate the potential health risks. Additionally, biomonitoring studies should be used to assess the total exposure to PAHs, which combined with personal air monitoring, would allow estimating the contribution of inhalation to the total exposure to PAHs.

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Exposure to Occupational Noise in Industrial Environment: Case Study

Rui Sardinha, Paulo Oliveira, Daniela Teixeira and Ana Peres

Abstract The objective of the present work is to develop and implement a methodology for evaluating health risks to workers due to occupational exposure to noise in the metalworking industry. Based on the available literature, in this paper the negative effects on the health of workers exposed to noise are identified, according to the types and levels of exposure to which they are subjected, and the activities, the methods and equipment are also characterized. The legal implications resulting from EU directives and Portuguese legislation, concerning the health protection of workers, the assessment of exposure risk to noise and the most suitable prevention and protection measures, are analyzed. This work primarily identifies and characterizes situations at a single plant at the manufacturing industry of metallic fences systems, where significant levels of exposure to noise may occur in various workplaces. Exposures were measured in various workplaces at the actual working plant. In the future, it is necessary to extend the studies to occupational health, considering the influence of other aggressors on hearing health, to minimize or eliminate such risks in the work environment.

Keywords Industrial acoustic · Prevention · Collective and individual protection

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1 Introduction

Noise is a significant element of disturbance to the health and well-being of industry workers. Thus, it is necessary to find fast and innovative ways to prevent the potential damages on workers, considering important aspects such as: the problem of noise and the damage it causes, noise legislation and safety, regulatory control over ergonomics and the relative comfort of noise, the control and technical prevention of noise, representative measurement of noise as a problem that exists, the possibility to improve and the need to innovate. The general objective of this work focuses on the development of an environmental noise management system in the industry to evaluate in real time the health risks of workers exposed to this problem, in an expeditious and organized way, to the development of adequate methods of prevention and protection that allow to reduce the level of exposure with a view to the continued protection of health.

It is intended to achieve this general objective through specific objectives such as: evaluation of the risks to the health of workers exposed to noise, protection against risk, protection policies and evaluation of the results obtained.

2 Effects of Noise on Health

The most known effect of noise on health is deafness. When aggression is not too severe, deafness only corresponds to functional impairment and is reversible. For instance, hearing a 90 dB(A) sound for seven days causes reversible deafness over a week, or hearing a sound of 100 dB(A) for an hour and a half causes reversible deafness that leads to about eight hours, to recover. Nevertheless, the exposure to 100 dB(A) for seven days causes a small permanent deafness (slightly more than 10 dB(A) of the audiometric zero) corresponding to organic lesion of the hair cells of the cochlea [1].

Human beings typically hear on a frequency range between 18 and 20 kHz, for social interactions, such as dialog the important frequencies are in the 500–2000 Hz range, for that reason disabling hearing loss is considered for that frequency range. Hearing loss due to industrial noise usually begins at a low disability frequency—4000 Hz—allowing, if periodical audiometries are performed, to detect those who will develop deafness and take the necessary measures, even at a non-disabling stage [1].

Short-term exposure and extremely high sound pressure can cause immediate hearing damage. Exposure to high sound levels can cause constant tinnitus, also called tinnitus, which may be the first sign that hearing is being affected by neuro-sensitive injury [1].

Several risks to the health and safety of workers are associated to noise exposure [2]:

- Hearing Loss: Excessive noise damages the hair cells of the cochlea, which are part of the inner ear, and can thus cause hearing loss.
- Physiological effects: There is evidence that exposure to noise has effects on the cardiovascular system, causing the release of catecholamines and rising blood pressure. Catecholamine levels in the blood [including epinephrine (adrenaline)] are associated with stress.
- Work-related stress: Noise in the workplace, even at very low levels, can cause stress.
- Increased risk of accidents: High noise levels limit the ability of workers to hear and communicate, increasing the likelihood of accidents.

Industrial noise is a pollutant of great interest that can negatively influence the health of exposed workers. So many experts have devoted their time to studying hearing damage caused by exposure to noisy environments for many years without proper use of the protective means, as demonstrated in the following studies.

López González, in his research with young workers of a textile industry in Cuba, found that workers who used hearing protection were less affected than others, and also influenced their time of use [3].

Other revised work on personal protective equipment suggests that simply removing them for 5 min in the noisy working day environment causes their effectiveness to thin and disappear [4], hence the great importance of the use of means of hearing protection to avoid damages to workers' health [5].

Tosal Suárez and his collaborators, measured noise levels in 1277 tasks in a Spanish sawing and wood preparation industry, finding that the predominant level was also higher than 90 dB(A) affecting 49.27% of the workers, also showing that there were no isolation booths for cutting machines and auxiliary installations where noise levels exceed 90 dB(A) [6].

López González, in a study of 88 workers in the textile industry, with more than eight months of work, concluded that the existing noise pollution had a negative effect on the health of the exposed personnel causing auditory changes [3].

Individual hearing protection should be used as a measure of recourse, that is only in cases where constructive or organizational measures are not feasible. However, the use of personal protective equipment has increasingly served to minimize the harmful effects of exposure to noise. The low cost and ease of implementation of this measure would be the preferred option [7].

3 Materials and Methods

The methodology for the development of the present work consists of the following steps:

1. Characterization of the metallurgical and metal working industrial unit;
2. Listing of activities developed and sources of noise and workplaces;
3. Noise levels measurements in all workplaces, based on a sample of 27 workplaces;
4. Spectral noise analysis at each workstation;
5. Assessment of daily personal exposure of workers to noise;
6. Presentation of control, prevention and protection measures, both collective and individual, for the elimination or reduction of the risk of exposure to noise;
7. Appropriate selection of hearing protectors that workers should use.

3.1 Description of Methodology Used

The methodology used in the study was applied as follows:

Based on the available literature, in this paper the negative effects on the health of workers exposed to noise are identified, according to the types and levels of exposure to which they are subjected, and the activities, the methods and equipment are also characterized. Despite the variety of sonometers available on the market, the operating principle of all of them is basically the same: a microphone, a processing unit and a reading unit [8]. Sound measurement equipment records sound pressures with total fidelity no matter the frequencies. Nevertheless, the human hear reacts differently to different sounds, depending on the frequency even if the produced sound has the same pressure [9].

Are analyzed the legal implications resulting from EU directives and Portuguese legislation, concerning the health protection of workers, the assessment of exposure risk to noise and prevention and protection measures.

Finally, evaluated and analyzed the occupational exposure to noise (Exposures were measured in various workplaces at the actual working plant). And depending on the levels of observed results, some preventive and protection measures were studied and proposed in order to minimize the risk of worker's exposure throughout engineering techniques, work organization and protection measures.

3.2 Characterization of the Case Study

This study was carried out in the metallurgical and metalworking company located in an industrial area. This company is dedicated to the production and marketing of metal fencing systems, as well as their installation, through external assembly equipment specialized in this type of service. The manufacturing facilities are composed of 5 large wings and a large area for manouvers:

1. Warehouse 1—Raw Material and Intermediate Product;
2. Soldering zone;
3. Straightening and Wire Cutting Machines zone, Manufacturing of Panels 3 and Cutting, Drilling and Application of Tube Rivets;
4. Zone of Machines for production of Panels 1 and 2, Section of Lacking and Packing;
5. Warehouse 2—Raw Material and Finished Product;
6. Load and unload area.

4 Results and Discussion

4.1 Emissions from Noise in Workplaces

Following the Portuguese legislation, Decree-Law no. 182/2006, of 6/09, which in 3.º article defines exposure limit values and upper and lower action values [10]. In 8.º article (Limit values of exposure) of the same legal document states that: The employer shall ensure that workers' exposure to noise at work is reduced to the lowest possible level and in any case not exceeding the exposure limit values laid down in 3.º article.

In situations where the exposure limit values are exceeded, the employer shall take immediate action to reduce exposure so as not to exceed the exposure limit values.

After the calculation of the noise levels $L_{EX,8h}$ dB(A), in the work places, it was observed that the workplaces most exposed to noise were associated to the machines that contributed with levels $L_{EX,8h}$ dB(A), of sound emission equal to or greater than 87 dB(A) 'exposure limit value' in particular:

No.18 → Angle Grinder/Grinding Machine: 93,3 dB(A)
No.23 → Cleaning Machine: 91,7 dB(A)
No. 2 → Elastic Netting Machine 1 and 2: 89,5 dB(A)
No.17 → Grinder Machine: 89,3 dB(A)
No. 5 → Wire Straightening and Cutting Machines 1 and 2: 89,1 dB(A)

After performing the calculations of the LCpico noise levels in dB(C), present in the workplaces, it was observed that the workplaces most exposed to impulsive noises were associated to the machines that contributed with LCpico sound levels recorded above 115 dB (C), namely:

No.18 →Angle Grinder/Grinding Machine: 119,7 dB(C)
No.10 → Post Cutting Machine 2: 118,5 dB(C)
No.23 → Cleaning Machine: 116,3 dB(C)
No. 9 → Post Cutting Machine 1: 116,0 dB(C)
No.16 → Spot Resistance Welding Machine: 115,7 dB(C)

4.2 Spectral Noise Analysis

By assessing the noise levels $L_{EX,8h}$ in dB(A) at workplaces/machines, it was verified that the most harmful machine in the development of deafness was the Rectifier contributing with a high level of sound emission, especially in the octave band of 4 kHz with 89.6 dB(A), followed by the Cleaning Machine in the workplace number 23 contributing with a high level of sound emission, especially in the octave band of 2 kHz with 87, 6 dB(A).

4.3 Actions to Be Implemented

Often neglected, noise induces a severe impact on people. A healthy human hearing responds to a wide range of sound pressure levels, from the hearing threshold to zero dB, with damage at 100–120 dB and with damage and pain at 130–140 dB. Due to the adverse impacts of noise on human health and in the environment, it is necessary to control it. The combination of techniques to be used for noise control depends on the extent of the noise reduction required, the frequencies of interest, the nature of the equipment used and the economic aspects of the available techniques [11].

Based on the definitions, the guiding topics on control, prevention and protection measures identify the most important actions to be implemented in this plant in terms of control, prevention and protection of workers in their exposure to noise:

Organizational or Administrative Measures:

- Adopt a human resources policy in which, at the level of selection of working personnel, the occupational health and safety factor is considered;
- Give priority, whenever possible, to the work that produces more noise, in time periods where there are fewer workers exposed to noise;
- Give the workers polyvalent technical-professional competences that allow them to perform all the tasks inherent to the production cycle;
- Reformulate/optimize the production plan, putting into practice a procedure where workers rotate through their different jobs, considering the exposure to noise associated with the sound pressure levels emitted by the machines.

Construction or Engineering Measures:

- Reflect on the possibility of making an investment in the fleet of machines, through the substitution of less noisy machines and tools with less potential for vibrations, in the cases identified as the most problematic;
- Guarantee that the maintenance plans of each machine and/or tool, established by the manufacturers, are met;
- Privilege and control a rigorous practice of maintenance and prevention machinery on the less recent park of machines and tools;

- On noise producing sources, use noise and vibration control devices and put into practice, if possible, some measures associated with immediate results, for example, through the replacement of machines, tools, more efficient and efficient accessories and procedures;
- When it is not possible to control the noise at the source, apply measures that control the noise in its propagation path, through the encapsulation, anti-noise panels, acoustic treatment of surfaces and cabins.

Individual Protection Measures:

- Promote and guarantee the use, on the part of the workers, of the hearing protectors identified as the ones that protect the most in regard to the global attenuation to noise exposure, throughout the working day;
- Taking into account the information collected about the most damaging octave bands in each workplace, identifying alternatives for more efficient hearing protectors, always bearing in mind the imperative of not compromising the audibility of audible alarm signals;
- Give importance to the comfort of workers with this type of individual protection, since depending on characteristics such as weight, pressure, texture, heat dissipation, absorption of perspiration, difficulty in carrying out tasks, difficulty of placement, decrease in intelligibility and even the aesthetic aspect, can be a determining factor for a less adequate and assiduous use.

Auditory Conservation Programs:

- Regularly accompany the risks and noise control measures, both in the internal plan and in the field of proper medical and health surveillance;
- Evaluate and analyse occupational noise, enabling a correct identification of workers likely to be exposed to excessive noise, as well as a timely update of significant alterations in working conditions, at the level of processes and/or of the equipment;
- Evaluate and analyse the auditory function of the workers, by virtue of which the hearing losses although they are not immediately noticed in the auditory perception of the individual, but gradually evidenced in audiometries;
- Train, raise awareness, inform and point out the workers, enhancing their attention and permanent integration in a problem that, although sometimes is not given much importance as it becomes secondary in face of the demands and work commitments of day to day, should be complemented with static signalling but also dynamic;
- Organize and archive the records, allowing the tracking of future situations of occupational diseases, as well as the assurance that a proper evaluation and performance of control and risk measures is carried out over the years.

5 Conclusions

In this study, an exhaustive bibliographical research focused on topics with the same scope of intervention was carried out, namely at the level of environmental impact caused by the noise generated in the metallurgical and metal mechanical industry. It is possible to conclude that the results obtained are similar to each other and that the proposed system of monitoring, analysis and control of industrial noise includes procedures and potentialities that represent evolutionary complementarity.

The study of the available noise studies showed that the production process of this industry generates quite high sound pressure levels, emphasizing the importance of working on large and well-characterized samples. It is therefore necessary to eliminate all situations that may introduce uncertainties in the interpretation of results.

In the researches carried out were also identified cases of high noise levels in the metallurgical and metalworking industry, nationally and internationally. These values were confirmed by the measurements carried out in this work, and therefore, due to this similarity, it can be affirmed that noise in this type of industry presents significant and quite varied levels. The Portuguese legislation, namely Decree-Law no. 182/2006, of 6/09, indicates that any worker who is exposed to a daily value of 80 dB(A) or higher should be considered as an exposed worker and shall apply to him all the requirements of medical surveillance, workplace monitoring and noise protection stipulated in said legislation.

Therefore, it is necessary to extend the studies to occupational health, considering the influence of other aggressors on hearing health, to minimize or eliminate such risks in the work environment.

The work started here has good conditions to be complemented with new research, resorting to epidemiological studies, with the location and characterization of activities where there is a significant risk of occupational exposure to noise.

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Assessment of the Indoor Gamma Dose Rates in 15 Portuguese Thermal Spas

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Abstract In Portugal, most of the average annual dose to which the population is exposed by natural sources is from radon (57%) and terrestrial gamma radiation (18%). In this study, the indoor gamma radiation dose rates were evaluated in 15 Portuguese thermal spas between 2011 and 2015. Gamma radiation dose rates were measured with a Geiger counter type GAMMA SCOUT® (GS3). The readings of the dose rate were hourly collected during a period of time ranging between 25 and 45 days, in different treatment rooms within each one the selected facilities: inhalation treatment rooms, thermal pools and vapors areas. All registered values for the gamma dose rates were lower than 1 mSv/year, and therefore the contribution of the external dose to the calculation of the annual effective dose is negligible.

Keywords Radon · Thermal spa · Gamma radiation · Distribution

1 Introduction

Radioactivity does not result exclusively from anthropogenic action, since the Earth has always been subject to cosmic radiation, forming part of some radionuclides.

Natural radiation includes cosmic radiation as well as the radiation arising from the decay of naturally occurring radionuclides. These, include the primordial

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radioactive elements in the earth's crust, their radioactive decay products, and radionuclides produced by cosmic-radiation interactions [2, 23].

The exposure to natural radiation occurs mainly in two ways: from external sources, which includes radionuclides in the earth and cosmic radiation, and by internal radiation from radionuclides incorporated into the body. The main routes of radionuclide intake are ingestion of food and water and inhalation. A particular category of exposure to internal radiation, in which the bronchial epithelium is irradiated by alpha particles from the short-lived progeny of radon, constitutes a major fraction of the exposure from natural sources [3, 6, 24].

In Portugal, most of the average annual dose to which the population is exposed by natural sources is from radon (57%) and terrestrial gamma radiation (18%) [5, 8].

Natural radiation from external sources is variable worldwide and this is due mainly to high or low soil concentrations of radioactive minerals. In particular, high concentrations of radioactive minerals in soil have been reported in several countries such as Brazil, India, and China. The high variations in doses received by the public from natural sources results from the fluctuations of concentrations in buildings [6].

Many human activities such as mining and milling of ores, extraction of petroleum, use of groundwater for diverse applications such as therapeutic treatments in thermal spas, modifies the natural background by concentrating the radionuclides in the exposure environment which can enhance significantly the radiation exposure [4, 9, 11, 12].

In thermal spas, the exposure to natural radiation occurs mainly from radon dissolved in water, which may be released to the indoors air, and its solid decay products but also from external gamma radiation, although the radon exposure will be of much higher magnitude. Water supplies makes only a small contribution to the indoor radon concentration but can be the predominant source in areas where the radon content of groundwater is unusually high [6].

In Portugal, the radiological surveillance of the environment is carried out through the Network of Continuous Monitoring of Radioactivity of the Environment (RADNET). The highest annual values of the gamma radiation rate in the national territory are recorded in area 1 and area 4 (Fig. 1).

Amaral et al. [1] conducted a study to determine the doses of gamma radiation in the external environment throughout the Portuguese territory, and verified that the dose of gamma radiation is higher in the districts of Braga, Viseu and Porto, due to the geological characteristics of these regions.

Silva et al. [17, 18] carried out a detailed study on exposure to external gamma radiation for indoor environments where high radon concentrations were observed [10, 13–22, 25]. Solid radon decay products are alpha and beta emitters but also gamma and they can contribute to the external dose from gamma radiation exposure [7].

The Decree-Law no. 222/2008 of 17 November, transposing Directive 96/29/Euratom of the Council of the European Union (repealed by Directive 2013/59/Euratom) lays down the basic safety standards for protection health and safety of

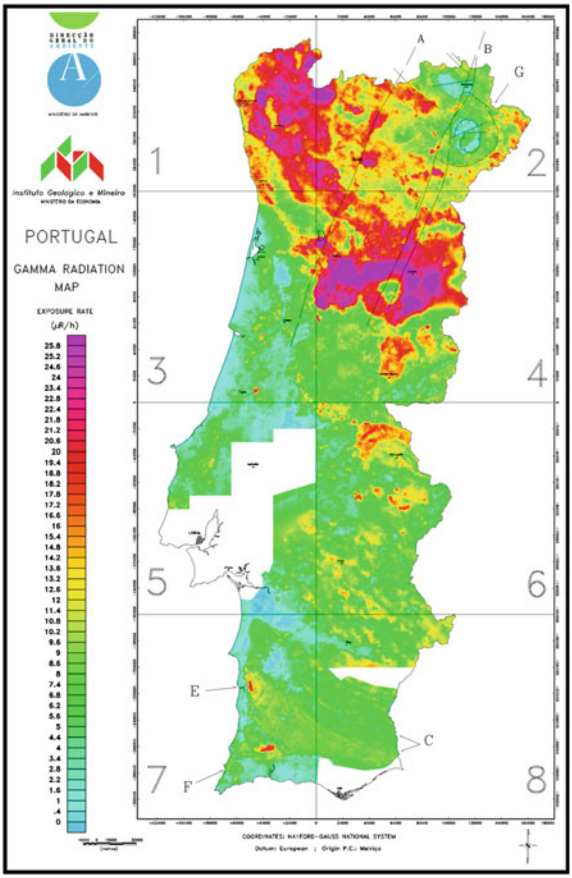


Fig. 1 Gamma radiation map Portugal natural gamma radiation letter from continental Portugal. A-fault of RéguaVerin; B-fault of Vilariça; C-flysch units of the Mira and Mértola formations are clearly visible in the radiometric image; D-São Pedro do Sul; E-volcanics mapped with the same geological behavior; Sienitic complex of Monchique, shows different geochemical characteristics, E and W a major fault; Morais Vinhais basic and ultra-basic G-complex

the general public and workers against the dangers arising from ionizing radiation, including work involving exposure to sources of natural radiation, such as thermal spas.

The objective of this study was to evaluate the indoor gamma dose rate in particular environments, such as thermal spas, and evaluate the contribution to total exposure dose. The assessment was carried out within 15 Portuguese thermal spas where both high and low indoor radon concentrations were registered.

2 Materials and Methods

The study was developed in 15 Portuguese thermal spas, distributed in the following districts: Viseu (4), Guarda (3), Braga (3), Porto (2), Castelo Branco (1), Aveiro (1) and Bragança (1).

Most of the occurrences of natural minerals in Portugal (with emergency temperatures between 20 °C and 76 °C) are located in the North/Center of the Country, due to the different geological and specific structural characteristics of the rest of the Portuguese territory.

To measure the indoor gamma dose rate in the selected thermal spas, a calibrated instrument able to measure either γ radiation, $\alpha + \beta$ and $\alpha + \beta + \gamma$, as well, was used (GAMMA SCOUT®—GS3). The equipment was used in the option gamma radiation dose rate measurements.

The Gamma-Scout is a Geiger counter with a wide measuring range and can be used to take instantaneous or time-integrated measurements.

The measurements were carried out for an exposure period comprising 25 and 45 days, within different treatment rooms of each ones of the thermal spas inhalation treatment rooms (ORL); thermal pool (TP); steam area room (SA) between 2011 and 2015.

Measurements of the gamma radiation dose rate almost always occurred simultaneously with measurements of radon concentration in indoor air.

In relation to the gamma radiation dose rate data, two tests for normality were applied to the data obtained for this variable: Chi-square test and Kolmogorov-Smirnov test.

The aim of this study was to analyze if the data of this variable presented a standard, to be followed later on another type of approach, namely the construction of a model, that would be applicable to all the Portuguese thermal spas and that explained the behavior of this variable foreseeing the risk of occupational exposure to radon for spa workers.

From the data collected for the radon concentration in indoor air it was possible to calculate the dose resulting from internal exposure by inhalation of radon and the annual effective dose combining the first dose with the dose resulting from external exposure given by the dose rate of gamma radiation.

3 Results and Discussion

The dose rate of gamma radiation was measured at 15 Portuguese thermal spas in the following places: TP, ORL and SA. The results are shown in Figs. 2, 3 and 4, respectively.

Gamma radiation dose rates were measured in the thermal pool of thermal spa 1 (TS1), 3 (TS3), 10 (TS10), 11 (TS11) and 14 (TS14) (Fig. 2).

The mean dose rate of gamma radiation in the thermal pool was 0.148 (TS1), 0.644 (TS3), 0.551 (TS10), 0.295 (TS11) and 0.332 (TS14) μSv/h, respectively. The highest value for the mean dose rate of gamma radiation was obtained in the thermal pool of TS3 (Fig. 2).

Regarding the variation of the gamma radiation dose rate data, it was found in the TS3 and TS10 thermal spas that the values obtained had the greatest variation.

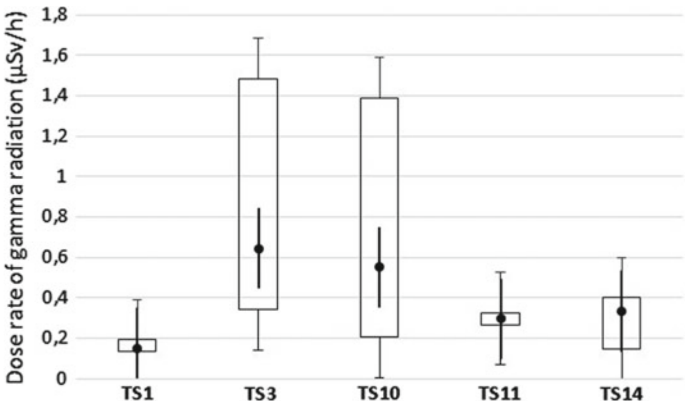


Fig. 2 Gamma radiation dose rate in TP

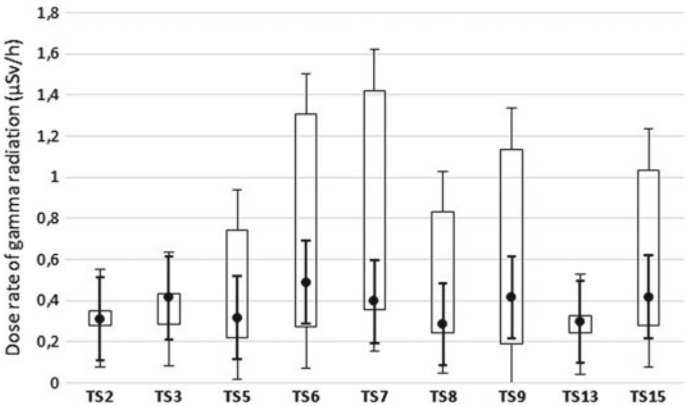


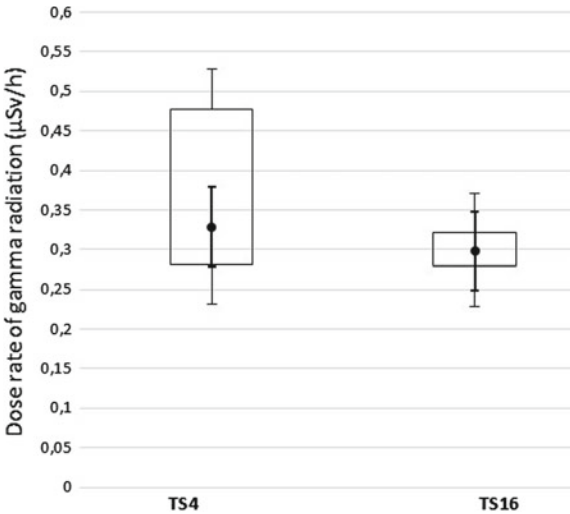
Fig. 3 Gamma radiation dose rate in ORL

However, it was in thermal spa TS1 that the data presented a lower variation, 0.132 and 0.192 µSv/h, respectively.

On the other hand, the gamma radiation dose rate values measured at the thermal spas TS2, TS3, TS5, TS6, TS7, TS8, TS9, TS13 and TS15 are very similar, in terms of data amplitude, to the values obtained for the dose rate of gamma radiation measured in the thermal pool of TS1, TS3, TS10, TS11 and TS14. This can be explained by the values of indoor air radon concentration and type of ventilation (mechanical ventilation) obtained at each spa site.

The highest value of the gamma radiation dose rate obtained in the TS6 ORL (0.490 µSv/h) is slightly lower than the highest mean value obtained in the TS3 thermal pool (0.644 µSv/h) (Fig. 3).

Fig. 4 Gamma radiation dose rate in SA



It is also verified that the values of the dose rate of gamma radiation in the ORL have a greater amplitude of values (TS6, TS7, TS9 and TS15) than the values of the dose rate of gamma radiation of the thermal pools. The reason for this data is the concentration of radon in indoor air, radon concentration in the water and type of ventilation (natural ventilation).

In relation to the dose rate values of the dose rate of gamma radiation obtained in SA, it is verified that the range of values is lower than the values obtained in the thermal pool and ORL. Gamma dose rate values range from 0.279 (TS16 minimum) to 0.478 (TS4 maximum) µSv/h (Fig. 4). This data can be explained by the type of ventilation (mechanical and natural) and radon concentration values in indoor air

For the values of the gamma radiation dose rate in the SA of the TS16, the data distribution is symmetric, since the median value (0.298 µSv/h) is identical to the mean value (0.298 µSv/h) (Fig. 4).

Considering the values of the dose rate of gamma radiation obtained in the TP, ORL and SA of the thermal spas, the distribution tests.

The adjustments to different types of distribution (Normal, Log-Normal) for the gamma radiation dose rate values were tested using the Kolmogorov-Smirnov (KS) test, and a significance level of 0.05 was adopted for the value of alpha (α).

In the case of the measurements of the gamma dose rate performed in the thermal pools, it was verified that the values obtained in the thermal spas TS1 and TS11, follows a normal distribution (Figs. 5 and 6).

On the other hand, the values of the gamma radiation dose rate measured in the ORL that followed a normal distribution were the values obtained in the thermal spas TS4, TS7, TS8, TS13 and TS15.

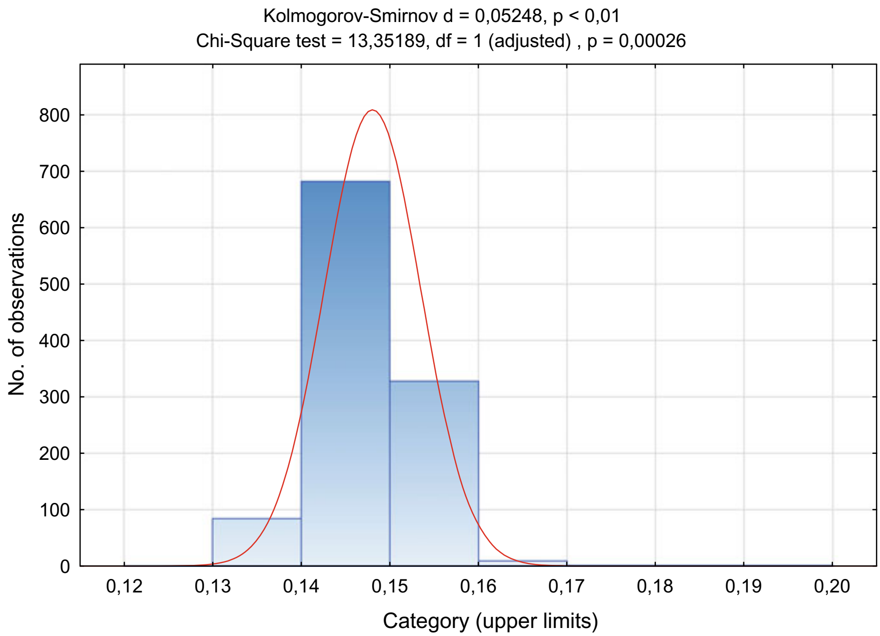


Fig. 5 Normal distribution for the gamma radiation dose rate values obtained in the TS1 thermal pool

4 Conclusions

No abnormal or too high values were detected for gamma dose rates in any situation and, therefore, the contribution of the external dose to the calculation of the effective annual dose is negligible.

Portuguese legislation (Decree-Law 222/2008) stipulates that professional activities in thermal spas may result in an annual effective dose higher than 1 mSv, and in these cases workers should be considered within an "existing exposure situation". Depending on the values of the annual effective dose, workers are classified into two categories (A and B) and specific measures are previewed for each one of these situations.

The purpose of Directive 2013/59/Euratom is to improve the radiological protection of workers who are or may be exposed to radiation, including workers who are exposed to natural radiation in the course of their professional activities, such as thermal spas. Therefore, according to the legislation, measures should be taken to monitor and control the radiation exposure in these professional activities, such as: (i) implementation of a monitoring system for the radiological protection of

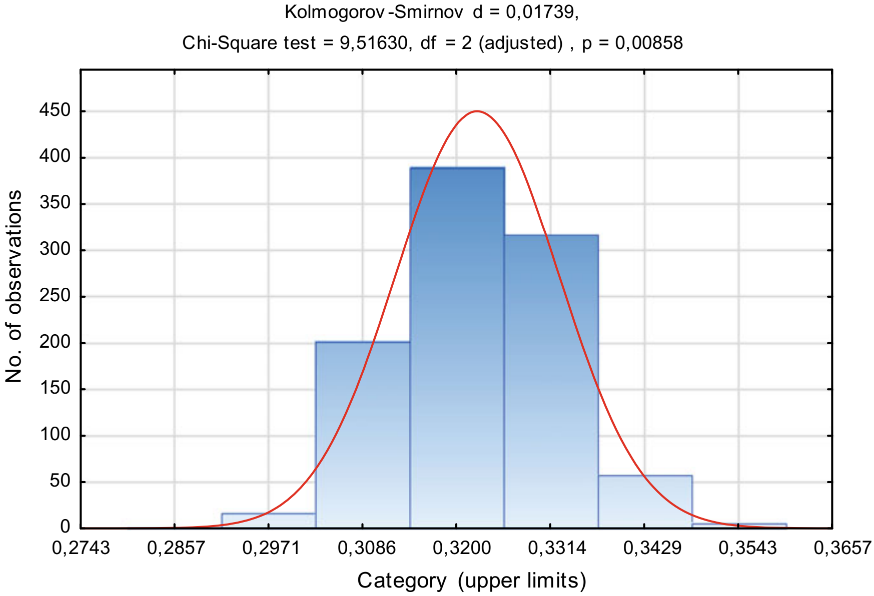


Fig. 6 Normal distribution for the gamma radiation dose rate values obtained in the TS11 thermal pool

workers; (ii) implement a radiological control plan for the facilities; (iii) ensure that these facilities have adequate and effective ventilation; (iv) health surveillance programs for workers.

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Volatile Organic Compounds Mixtures in Hospital Environment—The Common Exposure Scenario

Susana Viegas and Margarida Mateus

Abstract Chemical contamination is a reality in the hospital environment but unfortunately is rarely studied. However, if we consider that healthcare workers use a high diversity of products such as disinfectants, sterilizers, anesthetic gases, and much other is easy to recognize that workers and patients can be exposed to a complex mixture of chemicals. The aim of this study was to determine, through a review, the presence of volatile organic compounds (VOCs) mixtures in hospital environment. Results showed that a complex mixture of VOCs is normally present and this aspect should be reflected in the risk assessment process. Future research work must be developed related with the possible health effects caused by exposure to complex mixtures of chemicals.

Keywords Volatile organic compounds · Mixtures · Exposure · Hospitals

1 Introduction

Microbial contamination is already well reported in the hospital environment particularly due to the concern regarding hospital-acquired infections. However, chemical contamination is also a reality and unfortunately is rarely studied. Considering the kind of activities developed by the healthcare workers is possible to

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understand that workers and patients can be exposed to a high diversity of chemicals emitted during the use of several products such as disinfectants and sterilizers, anesthetic gases, and much other [1].

Moreover, most of the studies already developed are dedicated to specific compounds such as anesthetic gases (operating rooms), formaldehyde (pathology laboratories), or glutaraldehyde and ethylene oxide (disinfection units) [2]. However, exposure to volatile organic compounds (VOCs) is of particular concern mainly because the common exposure scenario is a complex mixture of several contaminants not allowing the prediction of the health effects associated.

Therefore, the aim of this study was to determine, through a review, the presence of VOCs mixtures in hospital environment.

2 Materials and Methods

A detailed literature search of PubMed was carried out using various combinations of corresponding descriptors and free text terms such as VOCs, VOCs mixture, hospitals, healthcare, and exposure. To restrict the results, the search was limited to studies published in English from January 2000 up to and including October 2018. Table 1 describes the inclusion and exclusion criteria adopted.

Table 1 Inclusion and exclusion criteria

Inclusion criteria	
Types of studies	Publication date 2000 (inclusive)—October 2018; studies reporting exposure to several VOCs in hospitals; English language; studies with quantitative data
Exclusion criteria	
Types of studies	Non english language; published pre 2000; grey literature/not published in a peer reviewed journal; dissertations/theses; proceedings; Published abstracts; reviews with only data already published

3 Results

A total of 5 studies met the inclusion criteria. Table 2 summarizes the characteristics of each of the studies included in this review. The abstracted data comprised first author and year of publication, hospital service/area where the VOC measurements were performed, VOCs detected (>LOD) and measured (>LOQ) and tasks associated with higher exposure or variables that influence exposure.

Table 2 Abstracted data from the studies included in the review

1st Author and year	Hospital service/area	VOCs measured (>LOD and LOQ)	Tasks associated with higher exposure/variables that influence exposure
Su et al. 2018 [3]	Cleaning	Ethanol, acetone, 2-propanol, d-limonene, α-pinene, chloroform	Tasks associated with instrument sterilizing and disinfecting associated with personal d-limonene and 2-propanol exposures. Surface and floor cleaning and stripping tasks were associated with exposures to chloroform, α-pinene, acetone, 2-propanol, or d-limonene
LeBouf et al. 2014 [4]	Cleaning and other services	2-propanol, acetone, benzene, chloroform, d-limonene, ethanol, ethylbenzene, hexane, p-xylene, methyl methacrylate, methylene chloride, o-xylene, toluene, a-pinene	The highest GM of ethanol was in nursing assistants and 2-propanol had the highest GM in medical equipment preparers. The highest personal exposure of acetone was in clinical lab tech and licensed practical nurse. Toluene had the highest personal exposure in clinical lab tech and medical appliance tech and limonene had the highest personal exposure in medical appliance tech. The highest total personal VOCs exposures were among nursing assistants
Bessonneau et al. 2013 [2]	Reception hall; patient room; nursing care; parasitol gy/mycology laboratory; post-anaesthesia care unit; endoscope disinfection unit	Aromatic hydrocarbons, halogenated hydrocarbons, alcohols, aldehyde, ketones, aliphatic hydrocarbons, ethers and terpene	Aromatic hydrocarbons: toluene with the highest concentrations in the room and from m.p-xyleno in the disinfectant unit. Aliphatic and halogenated hydrocarbons: chloroform with the highest concentration. N-hexane was the highest in laboratory. The highest concentrations are associated with disinfection practices. Alcohols: ethanol with the higher concentration Aldehydes: highest concentrations in nursing care. Terpenes: relevant in post-anaesthesia unit

(continued)

Table 2 (continued)

1st Author and year	Hospital service/area	VOCs measured (>LOD and LOQ)	Tasks associated with higher exposure/variables that influence exposure
Lu et al. 2006 [5]	Samples were collected in 4 hospitals: Injection room, ward, outdoor, clinic, emergency room	Formaldehyde, acetaldehyde acrolein, acetone, propionaldehyde, crotonaldehyde, 2-butanone, butyraldehyde, benzaldehyde, isovalerald hyde, cyclohexanone, valeraldehyde, m/o-tolualdehyde, hexaldehyde, dimethylbenzaldehyde, heptaldehyde, octylaldehyde, nonanaldehyde, decylaldehyde	High concentration of acetaldehyde, which was even higher than that of formaldehyde, might be resulted from the wide use of ethanol in hospital. Acetone was the most abundant carbonyl, followed by acetaldehyde, 2-butanone or formaldehyde. Toluene was the most abundant BTEX (benzene, toluene, ethylbenzene and xylenes) and the others were at similar levels
Takigawa et al. 2004 [6]	19 rooms in 2 hospitals.	Ethyl acetate, *n*-hexane, toluene, butyl acetate, ethylbenzene, *m*,*p*-xylene, *o*-xylene	Toluene was the more prevalent VOC

LOD Limit of detection; *LOQ* Limit of quantification; *GM* Geometric mean

4 Discussion

Results showed that a complex mixture of VOCs is normally present in the hospital environment. This mixture is dependent of multiple sources related to the products used in healthcare tasks but also cleaning activities. The contamination found in the studies is mainly due to the use of high number of chemical products, including cleaning and disinfectants products, alcohol-based products, pharmaceutical products and antiseptics, anesthetic gases, and laboratory products [2, 7]. Additionally, exposure to VOCs due to the usage of these products is very much dependent of the application conditions and risk management measures in place such as ventilation or protection equipment. For instance, and regarding cleaning products, inhalation exposure to aerosol particles of volatile and non-volatile ingredients can be facilitated during product spraying. Regarding the worst exposure scenario, this can happen when several cleaning tasks are performed in small and poorly ventilated spaces [7].

Special attention should be paid to possible health effects induced by exposures to such mixtures of VOCs even when each single compound exposure level is below the respective occupational exposure limit (OELs) or other reference values. Knowledge about the possible interactions between substances present in the workplaces is a key aspect since in most of the workplaces the workers are exposed to mixtures and not to a single agent to which an OEL has been defined [8, 9].

5 Conclusions

This study emphasizes the importance of considering that the real exposure scenario in occupational settings is characterized normally by an exposure to a complex mixture, in this case a complex mixture of VOCs. This aspect should be reflected in the risk assessment process and future research work must be developed related with the possible health effects caused by exposure to complex mixtures of chemicals, occurring also in the hospital environment.

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Part III
Occupational and Environmental Health

Burnout and Musculoskeletal Pain: A Health Promotion Intervention

Ana Paula Amaral and Gustavo Santos

Abstract Burnout may contribute to reduce physical and mental health. The objective of this study is the elaboration of a health education intervention based on compensatory workplace exercises to reduce burnout levels and musculoskeletal pain. The sample consisted of 49 administrative employees of a large hospital in São Luís, Maranhão, Brazil, 61.2% females and 38.8% males. Mean age 38.3 years (SD = 11.6), range between 20 and 61 years. The following instruments were applied: Sociodemographic questionnaire, Maslach Burnout Inventory—General Survey and the Nordic Musculoskeletal Questionnaire before and after the intervention. The intervention program consisted of 18 sessions of compensatory workplace exercises, held for five weeks, with a frequency of three sessions per week and a duration of 30 min each session. The results obtained before the intervention (items mean values) suggest moderate Exhaustion (2.50 ± 0.938), higher Cynicism (3.27 ± 0.917) and lower Professional Efficacy (1.81 ± 0.406). Concerning musculoskeletal pain, it was more prevalent in the shoulders (69.4%) and back (upper 67.3% and lower 65.3%), followed by the thighs and neck (both 61.2%). The results showed a significant decrease in the levels of the three dimensions of burnout and in all musculoskeletal symptoms evaluated after intervention ($p < 0.05$). After this analysis, it was concluded that the program fulfilled the objectives initially proposed, demonstrating the relevance of the implementation of health education programs in the scope of occupational health.

Keywords Burnout · Musculoskeletal pain · Health education

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1 Introduction

An extensive literature focused on causes and consequences of burnout has emerged since the first studies of Freudenberger and Maslach. Burnout is a response to prolonged stressors at work and is defined as a chronic syndrome which includes exhaustion, cynicism, and reduced professional efficacy [1]. Research has shown that burnout may contribute to reduced emotional and physical health and has shown that employees who are at risk of burnout show impaired job performance [2–4].

Work stress leads to various symptoms. For instance, physical symptoms comprise headache, motion sickness, muscular or musculoskeletal pain and tension, gastrointestinal problems, sexual problems, sleep disturbances, loss of appetite, hypertension, shortness of breath and chronic fatigue [5]. Social manifestations include isolation, irritability, skepticism and little involvement with co-workers and clients [6]. Behavioral symptoms are hyperactivity, health-risk behavior, impulsivity, loss of initiative and increase of additive behaviors [7]. Attitudinal manifestations such as dehumanization, impatience, insensitivity, low self-esteem, irony, paranoia, loneliness, indifference and cynicism to colleagues and clients [8]. Finally, other manifestations at work, such as intention to quit employment, absenteeism, low productivity, delays, accidents, thefts and negligence [6].

Some studies have analyzed the relationship between burnout, physical health and job factors [9]. For example, individuals working in manufacturing, pharmaceuticals, and school environments, have been observed to experience higher burnout and increased risk of developing regional musculoskeletal pain when compared to others[2]. The results of a study with primary care providers suggested that increasing number of hours worked per day, severity of pain in the neck/shoulder area and severity of pain in the right wrist were associated with an increased risk of burnout [3].

Although several studies have been conducted to assess burnout and musculoskeletal symptoms independently, we are not aware of any studies that evaluated the impact of a health promotion intervention on burnout and musculoskeletal pain among administrative employees.

This paper describes the effects of a health promotion intervention (based on compensatory workplace exercises) on burnout and musculoskeletal pain in workers of the administrative sector in a public hospital. We aimed to (1) Reduce burnout levels; (2) Reduce possible musculoskeletal pain in the body segments evaluated; and (3) Promote changes in the institution, implementing good practices with a view to a healthier life.

2 Methods

The study uses a pre-test post-test experimental design. The independent variable is a health promotion intervention based on compensatory workplace exercises. The dependent variables are musculoskeletal pain and burnout.

The ethical requirements were respected. The research aims, the procedures and the expected duration of the study were explained to the participants. Confidentiality was ensured as well as the voluntary nature of the participation.

We followed three steps: (1) Evaluation pre intervention with the Maslach Burnout Inventory—General Survey (MBI-GS), the Nordic Musculoskeletal Questionnaire (NMQ) and a Sociodemographic questionnaire; (2) Elaboration and implementation of the intervention program focused in sessions of compensatory workplace exercises; (3) Evaluation post intervention with MBI-GS and NMQ.

2.1 Participants

Initially, 63 subjects were recruited to participate in the study. Of the 63 subjects, 49 subjects participated in all the phases of the study. Participants were 49 workers (administrative employees) of a large hospital in São Luís, Maranhão, Brazil, 61.2% females and 38.8% males. The mean age was 38.3 years (SD = 11.6), range between 20 and 61 years.

2.2 Measures

Burnout. To measure Burnout we used the Brazilian version [10] of the Maslach Burnout Inventory—General Survey (MBI-GS) [11] MBI-GS is a 16-item self-report measure designed to assess an individual's level of burnout.

The MBI-GS assesses an individual's level of experienced burnout on three domains. These ones are Exhaustion (six items), Cynicism (four items) and Professional Efficacy (six items). Statements related to burnout are measured on a seven-point Likert scale from zero (never) to six (Every day) [12] The first dimension (Exhaustion) measures fatigue without referring to other people as the source of one's tiredness. The second dimension (Cynicism) reflects indifference or a distant attitude towards work in general, not necessarily with other people. Finally, Professional efficacy encompasses both social and non-social aspects of occupational accomplishments [13].

After completing the MBI-GS, an individual's burnout can be categorized into three levels on the three domains: low, moderate and high. For the analysis of the results obtained in this study, the cut-off points of Mclaurine [14] were considered.

Regarding the total value of Burnout, values up to 1.33 are considered low, between 1.34 and 2.43 moderate and above 2.43 are high values.

Musculoskeletal pain. To measure musculoskeletal pain we used the Brazilian version [15] of the Nordic Musculoskeletal Questionnaire (NMQ) which was developed from a project funded by the Nordic Council of Ministers [16]. This is one of the main instruments used to assess the severity and impact of musculoskeletal symptoms in occupational groups [17].

The NMQ allows the identification of musculoskeletal symptoms by the worker, as well as the need of the worker to search for health resources and the interference of the symptoms in the performance of the work activities. In the present study, only the results regarding the identification of musculoskeletal symptoms were considered.

The body map of the NMQ included the following anatomic localizations: mouth/jaw; neck; shoulder left; shoulder right; upper back; elbow left; elbow right; lower back; hand/wrist left; hand/wrist right; hip/upper leg left; hip/upper leg right; knee left; knee right; foot/ankle left; foot/ankle right.

2.3 Intervention Program

The intervention consisted of 18 sessions of compensatory workplace exercises, each session lasting 30 min, three times a week, during six weeks.

The protocol adopted in this study included the following exercises and techniques: postural exercises, segmental stabilization and stretching in muscular chains.

The 18 sessions were divided into three phases with six sessions for each proposed activity. The first six sessions prioritized activities of free active stretching with static position in the stretching movement, in the following muscle groups: neck, upper limbs, trunk and lower limb. In the second phase, the teaching of postural exercises that can be done in the workplace was prioritized, with an example in an auditorium with the purpose of promoting physical exercises in the workplace. Finally, during the last six sessions, muscle chain strengthening activities were performed in isometric postures for the three segments started in the first sessions.

2.4 Statistical Analysis

A descriptive statistical analysis was performed with measures of central tendency and dispersion. To evaluate the normality of distribution of variables, Shapiro–Wilk test was used.

In order to compare the means scores before and after the intervention program, the t Student test were used for normally distributed data. When variables have not a normal distribution we used the Wilcoxon test. The level of significance used for the interpretation of the tests was $p < 0.05$.

3 Results

3.1 Burnout

After analyzing the mean values of each item of the MBI-GS scale before the intervention, most of the items of Exhaustion dimension presented moderate means (2.1–3.19) or high (>3.20). In relation to Cynicism, most of the items correspond to high levels (>2.20). Regarding Professional Efficacy, all the items presented low values (<4.0).

Comparing the mean values of Burnout (total and dimensions) before and after the intervention, the differences found were statistically significant ($p < 0.05$) (Table 1). The results showed that there was a significant decrease in the levels of Burnout (total), Exhaustion and Cynicism (1.48, 2.36, 3.00, respectively) and an increase in Professional Efficacy after the intervention (from 1.81 to 4.25).

3.2 Musculoskeletal Pain

Regarding the results obtained in the NMQ, the most frequent pain symptoms are in the shoulders (69.4%), in the upper back (67.3%), and lower back (65.3%), followed by the thighs and neck (both with 61.2%) and hands/wrists (57.1%), foots/ankles and knees (both with 44.9%). The less frequent symptoms are in elbows (28.6%).

As we can see at Table 2, the results showed there was a decrease in mean values of all musculoskeletal symptoms after the intervention program. The difference between the means of musculoskeletal symptoms before and after the intervention is significant ($p < 0.05$).

Table 1 Mean values of MBI-GS items in pre and post-test

Variable	M ± SD		*p*-value
	Pre-test	Pos-test	
Burnout (T)	2.43 ± 0.606	1.48 ± 0.562	0.003**
Exhaustion	2.50 ± 0.938	2.36 ± 0.823	0.001**
Cynicism	3.27 ± 0.917	3.00 ± 0.967	0.006**
Professional Efficacy	1.81 ± 0.406	4.25 ± 0.568	0.000***

M = Mean; SD = Standard Deviation. *$p < 0.05$; ** $p < 0.01$; ***$p < 0.001$

Table 2 Mean values of MSQ items in pre and post-test

Variable	M ± SD		p-value
	Pre-test	Pos-test	
Neck	1.61 ± 0.492	1.10 ± 0.306	0.003**
Shoulders	1.69 ± 0.466	1.14 ± 0.354	0.014*
Upper back	1.67 ± 0.474	1.14 ± 0.354	0.009**
Elbows	1.29 ± 0.456	1.12 ± 0.331	0.031*
Hands/wrists	1.57 ± 0.500	1.14 ± 0.354	0.031*
Lower back	1.65 ± 0.481	1.10 ± 0.306	0.001**
Hip/upper legs	1.61 ± 0.492	1.10 ± 0.306	0.005**
Knees	1.45 ± 0.503	1.10 ± 0.306	0.021*
Foots/ankles	1.47 ± 0.504	1.08 ± 0.277	0.017*

M = Mean; SD = Standard Deviation. *$p < 0.05$; ** $p < 0.01$; ***$p < 0.001$

4 Discussion

In the first evaluation, the mean scores of exhaustion, cynicism and professional efficacy are 2.5, 3.3, 1.8, respectively. Paired results were referred by several studies. For example, in the study of Albaladejo et al [18]. the mean scores of exhaustion and cynicism are 2.8 and 3.5 respectively. Other studies underline that burnout affect mental, social and physical well-being [5–7]. Concerning physical well-being, the shoulders, back (upper and lower), hips/thighs and neck were the most commonly reported body regions for musculoskeletal pain in this study. These results are consistent with previous research findings, who consistently reported neck, shoulders and lower back body regions [3, 19–21].

After the intervention, the mean scores of burnout (total score), exhaustion, cynicism and all musculoskeletal symptoms decreased significantly. Professional efficacy increased significantly. Concerning the effects of compensatory workplace exercises in musculoskeletal symptoms, our results are consistent with several studies, which reported a significant improvement in the musculoskeletal symptoms identified in the workers, minimizing health problems [22–24].

Studies regarding the effects of compensatory workplace exercises in burnout are not common, and the existing ones are not in line with our results. For example, Freitas-Swerts and Robazzi [22] did not find significant reduction in the scores of work stress after undergoing workplace exercise.

Programs that include workplace exercises are an essential tool for those professionals whose work routine becomes exhausting, with inappropriate positions; these programs can increase self-esteem, productivity and improve the quality of life of the workers [25].

The associations between musculoskeletal pain and burnout are underlined in several studies and may explain our results. Exhaustion as one of the precursors of musculoskeletal pain, is associated with lack of energy and enthusiasm and it is reflected in the body in the form of pain and intense fatigue [26, 27]. On the other hand, programs which promote stretching, muscle relaxation and flexibility have physical and mental benefits such as helping to increase concentration and improve self-esteem [28].

5 Conclusion

The results obtained in this study suggest the importance and effectiveness of the implementation of compensatory workplace exercises in the reduction of burnout and musculoskeletal symptoms, alerting the institution and the participants involved in the study to the importance of this methodology.

However, this study had several limitations. The main limitation was the duration of the intervention which was shorter than intended, due to organizational issues. For example, the absence of an appropriate place for a longer period and difficulties with the employees availability to participate. Another limitation was the lack of a control group to compare the obtained results.

Further research is needed to better understand the association between musculoskeletal pain and burnout and the impact of compensatory workplace exercises in these variables. Also, longitudinal studies are required to clarify the associations between the mentioned variables. In order to promote good practices at the institution, the engagement of the organizations in health programs is a requirement in order to allow the planning of longer interventions.

Finally, this study was a pioneer initiative, with a low cost and a significant impact on the health of the administrative employees. In the future it will be important to promote changes not only in microsocial sphere of the work, but also in the wide range of macro-organizational factors. To replicate this health promoter program and apply to other professionals will be a challenge in the scope of occupational health.

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The Effect of Prolonged Sitting on Students

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Abstract A questionnaire was applied on a sample of 392 students from four universities in order to study the effect of prolonged sitting in classrooms. The results indicated that students have corporal, behavioural, cognitive and psychological symptoms in terms of either frequency or intensity during prolonged sitting in the study seat. The results also showed that students use various ways and means to cope with this prolonged sitting. It was suggested that the design of seats and tables at the university should be adapted to fit the physical dimensions of the students. In addition, there is an absolute need to well planned studying hours and suitable different types of breaks.

Keywords Prolonged sitting · Students · Symptoms · Classrooms · Furniture

1 Introduction

Prolonged sitting is usually linked with studying at the university whether in classrooms or in what is required by the reading process, like libraries, computer… etc. However, sitting for a long time may lead to the relaxation of the abdominal muscles (Sedentary Tummy), and to the poor distribution of the weight while sitting, which can in turn reduce the blood flow in the buttocks and thighs due to the pressure of the weight on the soft tissues [1]. This can result from the expansion of pelvic blood vessels that can lead to health problem such as haemorrhoids [2].

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Thus, it has been confirmed that sitting is associated with many harmful effects resulting from the non-adaptation of the chair design to suit the over time user. These effects appear on the structure of blood vessels and the possibility of potential venous thrombosis [3–5]. Sitting in many cases involves flattening or curling the spine, which not only affects the digestive and respiratory system but also imposes stress on the back muscles and increases pressure on the intervertebral discs. [6–11]. It has been found for example, that the intra descale pressure on the vertebral discs when sitting was more than during standing [11], and both the activity of the back muscles and the disc pressure varies according to the variation of the sitting posture. The forward bend can impose a high intra descale pressure more than that resulting from straight sitting [6, 11].

Many studies have pointed out the incompatibility between the equipment of the classrooms (chairs and tables) and body dimensions of students. A study carried out at Michigan School has concluded that there was a significant degree of incompatibility between Physical dimensions of students and available chairs and tables [12]. A large discrepancy between the physical dimensions of scholars and the school furniture represented in tables and chairs has also been confirmed [13]. Another study found that there was a mismatch between body dimensions of students and dimensions of chairs and table used at the university [14]. Similarly, it has been pointed out that the college's facilities were far from consistent with the anthropometric measurements of the students [15]. Furniture dimensions available at the level of classrooms, auditoriums and libraries used at the University of Algiers 2 were compared with the anthropometric measurements of students. The results showed that there was an inconsistency between them. This may be one of the negative factors affecting students and their reluctance to attend classes. There are even days where they are forced to sit in these classrooms for a period of up to 6 or 8 h. Let alone what is expected from them to continue studying at home. For example, the value corresponding to five percentile for the knee height to the ground is 39 cm, while the height of the seat surface of the various chairs is more than 45 cm, which means that most students suffer from excessive height of the chair surface [16].

Hence, this study aims at looking at the effects of this mismatch on corporal, behavioural, cognitive and psychological symptoms that may appear because of prolonged sitting by students. In addition, to how do they cope in order to face this poor compatibility between their physical dimensions and classrooms furniture.

2 Methods

2.1 Tools Used

The questionnaire consists of five axes: corporal, behavioural, cognitive and psychological symptoms of students during prolonged sitting in the study seat, as well as ways to face this prolonged sitting. The subjects of the various topics were identified after carrying many interviews with students. The reliability and consistency of the questionnaire was also measured. Students were asked to answer the frequency of the perception of various symptoms and effects of prolonged sitting on a five-point scale ranging from rare to permanent, and from zero to severe degree for the intensity of symptom. The (SPSS) package version 17 was used in this study to calculate the means, standards deviations and Friedman ranking means test were calculated in this study.

2.2 The Sample

The questionnaire was applied on a finale sample of 392 students. They were distributed among the following four universities: 55.6% from the University of Algiers 2, 12.4% from the University of Constantine, 17.4% from the University of Batna, and 14.6% from the University of Tiaret. 64% of them were females and 36% were males. 88.8% are single and 11.2% are married. Their ages range from 18 to 45 years. Their weight ranges from 45 to 100 kg. Their height range from 150 to 187 cm.

3 Results

Friedman ranking means test was applied to rank the frequency as well as the intensity of corporal, behavioral, cognitive and psychological symptoms during prolonged sitting. The results showed symptoms that occupied the first five places according to their levels of frequency and intensity as it shown in table: (1) and (2), respectively.

The results of the current study showed that students suffer from frequency of various corporal symptoms in terms of their either frequency or intensity. This could be an attempt to avoid discomfort. The latter could be generated because of using chairs or tables poorly designed or rather inappropriate. However, some of these corporal symptoms like headache and sleepiness might not necessary be related to bad design of furniture. Moreover, the results indicated that student are also suffering from behavioral, cognitive and psychological symptoms with a quit similarity in terms of frequencies and degrees of intensities just like those of corporal symptoms or even a bit higher means. The results also indicated that students use many ways to cope with effects of prolonged sitting on the study chair (Tables 1 and 2).

Table 1 Symptoms frequency

Symptoms type	Symptoms	Mean	SD	Mean rank	χ^2
Corporal	1. Headache	3,13	1,466	23,12	321,469
	2. Back pain	3,09	1,535	23,11	
	3. Sleepiness	3,10	1,509	23,01	
	4. Permanent fatigue	3,11	1,391	22,89	
	5. Difficulty to stand	3,02	1,430	22,58	
Behavioural	1. Checking the time	3,35	1,360	12,27	72,025
	2. Very fidget	3,27	1,294	11,74	
	3. Playing with the pen	3,24	1,306	11,53	
	4. Showing frown Face	3,22	1,489	11,49	
	5. Speak to colleagues	3,24	1,297	11,48	
Cognitive	1. Difficulty to follow lessons	3,29	1,254	8,66	76,473
	2. Dispersion of attention	3,30	1,311	8,57	
	3. Deviation of the mind	3,23	1,260	8,44	
	4. Difficulty of absorption	3,24	1,169	8,43	
	5. Weak memory	3,20	1,202	8,24	
Psychological	1. Boredom	3,31	1,349	18,50	156,523
	2. Discomfort	3,22	1,384	17,83	
	3. Anxiety	3,18	1,312	17,64	
	4. Frustration	3,19	1,264	17,49	
	5. Lack of motivation to study	3,19	1,291	17,39	
Coping	1. Put the leg on the leg	3,26	1,419	9,31	65,824
	2. Moving legs	3,17	1,366	9,02	
	3. Leaning back on the chair	3,16	1,333	8,91	
	4. Asking to get out	3,18	1,350	8,87	
	5. Change the sitting position	3,16	1,434	8,85	

4 Discussion

It is perhaps expected as pointed out by previous researchers for students to have physical complaints as the results of mismatch between their body dimensions and the classroom furniture. Especially symptoms like back pain, permanent fatigue and difficulty to stand, which might simply be interpreted as discomfort. This in line with some previous studies that pointed out that the students' perception of discomfort related to the furniture was relevant and that complaints of discomfort and/or pain may be related to prolonged sitting. The body parts with more complaints of pain were the head, neck, shoulders, and lumbosacral region. The longer they remained sitting, the greater the incidence of pain complaints [17].

Table 2 Symptoms intensity

Type	Symptoms	Mean	SD	Mean rank	χ^2
Corporal	1. Sleepiness	3,36	1,361	24,14	287,425
	2. Difficulty of walking	3,11	1,317	22,74	
	3. Back pain	3,13	1,290	22,68	
	4. Headache	3,14	1,391	22,45	
	5. Difficulty of standing	3,12	1,299	22,35	
Behavioural	1. Checking the time	3,28	1,284	11,95	63,881
	2. Very fidget	3,24	1,260	11,71	
	3. Desire to move and stand	3,21	1,255	11,69	
	4. Speak to student nearby	3,18	1,233	11,42	
	5. Neglecting study timing	3,19	1,397	11,36	
Cognitive	1. Difficulty to follow lessons	3,28	1,081	8,53	46,944
	2. Dispersion of attention	3,27	1,086	8,50	
	3. Deviation of the mind	3,22	1,050	8,41	
	4. Feel of complexity of the study	3,21	1,226	8,33	
	5. Lack of concentration	3,18	1,076	8,29	
Psychological	1. Boredom	3,23	1,228	18,04	98,864
	1. Concern	3,17	1,249	17,54	
	3. Frustration	3,18	1,190	17,48	
	4. Lack of motivation to study	3,20	1,263	17,33	
	5. Mood swings	3,13	1,236	17,13	
Coping	1. Put the leg on the leg	3,04	1,265	8,97	18,406
	2. Put the feet under the chair	3,03	1,094	8,78	
	3. Rotate the two legs aside	3,05	1,167	8,74	
	4. Leaning on the table	3,00	1,095	8,69	
	5. Change the sitting position	3,01	1,235	8,64	

However, suffering from headache and sleepiness and even more from behavioral, cognitive and psychological symptoms during prolonged sitting, may raise the question if the problem is related to the bad design of the classrooms furniture only. It is supposed that this would result in discomfort, which is usually defined as the absence of pleasure. This absence of pleasure is not unbearable but distracts the attention of the individual from whatever activity he is pursuing. Discomfort can be painful and may make the affected person neglect his activity gradually. In such a situation, discomfort can be interpreted as pain. Hence, there is a relationship between pain and discomfort. The latter may be a precursor unbearable pain. Discomfort is also present in pain but its definition deals with negative psychological injuries. Pain has obvious sensory qualities but is also a function of the emotional and motivational characteristics of the individual [18, 19]. The posture adopted by students is affected by internal and external constraints. The internal constraints imposed for example by amplitudes of joint movement and fatigue from continuous static contraction of postural muscles results in discomfort and pain. The external constraint are imposed by the type of activity and its environment. These two last factors cannot be treated separately as they interact with each other.

This could be explained by the fact that the effect of prolonged sitting is not limited to just corporal symptoms caused by poor compatibility between their physical dimensions and classrooms furniture, but it is perhaps related to other health concern from sitting too much. Indeed recent studies have raised health risks associated with sitting too much not only at work but especially at school. It was concluded from one longitude study that in men, higher occupational energy expenditure levels and fewer occupational sitting hours were associated with decreased hazard ratios for colon cancer, particularly distal colon cancer. [20]. A similar study pointed out that reduced sitting time was associated with telomere lengthening in blood cells in sedentary, overweight 68-year-old individuals participating in a 6-month physical activity intervention trial [21]. Another study found that long sitting times were associated with exhaustion during the working day, decreased job satisfaction, hypertension, and musculoskeletal disorder symptoms in the shoulders, lower back, thighs, and knees of office workers [22]. Many studies have confirmed The Psycho-Physiological Effects and Symptoms among Computer Operators [23].

5 Conclusions

Prolonged sitting by students leads to corporal, behavioural, cognitive and psychological symptoms. However, these symptoms might well have somehow beneficial aspects as they warn that something biologically harmful is happening to our bodies [19].

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Real Time Fatigue Assessment: Identification and Continuous Tracing of Fatigue Using a Physiological Assessment Algorithm

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Abstract Fatigue decreases performance and physical strength causing incidents and accidents in operational settings. An algorithm has been developed for the management of fatigue, in which assessment of monitored physiological parameters determines different categories of alert alarms with the aim of advising timely interventions and preventing further physical impairments. In this study, the performance of the algorithm was retrospectively evaluated within laboratory trials. Five soldier participants were referred for assessment and, outcomes demonstrated that the algorithm evidenced the different stages of training and the resulting physical demands on subjects by means of their physiological response throughout the exercises. It is concluded that the developed tool, with further adjustments, has the potential to improve fatigue management, allowing early detection of potential physical impairments, reducing the number of medical evaluations and minimizing unnecessary delays in treatment.

Keywords Fatigue · Physiological monitoring · Assessment algorithm

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1 Introduction

Fatigue is a complex and multifaceted phenomenon. In general, it can be understood as a condition involving decreased ability of individuals to perform activities at the desired level due to lassitude or exhaustion of mental or physical strength [1]. Fatigue degrades performance and well-being leading to error, incident, and accident in operational settings [2]. Because of the potential impact of fatigue on health, safety, and productivity, any organization in which individuals work extended hours, or hours during which people typically sleep, can benefit from addressing fatigue in the workplace. This is particularly important for safety-sensitive operations such as the transportation, health care, and energy industries. Military operations are not exempt from this. Besides typical operational stressors, soldiers, more than any other working group, must deal with stressful situations that can lead to a state of fatigue, non-functional overreaching and eventually overtraining [3]. As physiological stressors compromise health and performance, human performance optimization involves strategies to sustain both in the face of these stressors. Physiological modeling defining human tolerance limits and the effect of moderating factors provide scientifically based strategies to interventions that ultimately involve the way individuals and teams eat, rest, train, and are equipped [3].

In this regard, a novel algorithm for fatigue assessment through physiological monitoring was developed and therefore, the aim of this study was to evaluate its applicability within laboratory trials.

2 Methods

2.1 Participants

For the goals of this study, data from 5 male subjects during a maximum oxygen consumption (VO_{2max}) test, performed as part of a project executed from January 2014 to December 2015, were compiled. Participants were elements from the Portuguese Army. They all gave their informed written consent prior to investigative procedures and were briefed on purpose, potential risks and benefits of the experiences. In general, recruited subjects did not present cardiac, vascular, pulmonary, or any allergic diseases, were considered mentally healthy and were not prescript with any regular medication. Participants were aged 22.4 ± 1.14 (years $\pm$ SD) and weighted 78.1 ± 14.41 (kg $\pm$ SD). Their general characteristics are presented in Table 1.

Table 1 Participants' anthropometrics

Assigned code	Birth date	Age (until 20.06.14)	Weight (Kg)	Height (m)	BMI (Kg. m^{-2})	Body fat (%)
M02	09.10.91	22	75.8	1.772	24.14	6.8
M03	27.04.92	22	71.5	1.708	24.51	13.7
M04	14.11.89	24	69.6	1.779	21.99	8.9
M05	23.09.92	21	70.1	1.736	23.26	6.1
M06	25.07.90	23	103.5	1.725	34.78	23.7

2.2 Equipment

VO_{2max} was assessed on a General Electric cycle ergometer (model T2100). The test was performed until complete exhaustion. During the trials, the oxygen concentration was continuously measured and monitored in real time with Cosmed K4b2 equipment. Additionally, physiological parameters were recorded as follows: skin temperature (T_{sk}) with temPlux thermometers, heart rate (HR) through electrocardiography (ECG) with a General Electric equipment and brain activity through Electroencephalography (EEG) with an Emotiv EPOC EEG headset. For core temperature (T_{co}) recordings, ingestible thermometer pills from Vital Sense were used. Ratings of perceived exertion (RPE) were measured verbally using the modified Borg's Scale [4]; subjects rated their level of fatigue on a scale from 0 (none) to 10 (maximal exertion) during and immediately at the end of the maximal incremental test. Finally, obtained data were analyzed by the annotated algorithm developed using Pandas, a Python 3.6 library for data analysis and statistics. All trials were executed according to pre-established validated protocols, obtained data was saved in digital files and events chronology was recorded in log diaries.

2.3 Experimental Design

As described in the literature, VO_{2max} is an indicator of the aerobic power and the physical condition of a given subject [5]. In this study, VO_{2max} was evaluated using an incremental treadmill protocol. Initially, the subjects performed a 5-min warm-up run at low speed on the treadmill (8 km/h). After resting (5 min at 4 km/h), subjects performed a progressive and continuous test, to exhaustion, on the treadmill without slope at an initial speed of 10 km/h, with load increments (1 km/h) every 2 min.

3 Physiological Assessment Algorithm

Physiological monitoring records were assessed using a novel algorithm that enables analysis and provides an integrated assessment of parameters per minute.

The proposed algorithm takes the monitored data and uses recordings as input parameters. It standardizes received values resampling them to a minute frequency and determines an alert alarm per minute according to 9 assigned categories (Table 2), that refer from a good overall health status (alarm 1) to 4 different levels of fatigue (alarms 2, 3, 4 and 5) and possible extreme scenarios of bad health status (alarm 6) or potential faint (alarm 7) or absence (alarm 8). Special consideration is also given when the sensor is not functioning correctly (alarm -1). Finally, generated assessments are then exported to an Excel file under the name of 'Results'.

In general, fatigue alarm levels are verified first and whenever one of the pre-established criterions is not met, fatigue alarm level undergoes one category. In other words, after verifying sensor status, the categorization process begins from the highest fatigue alarm, and only if none of the fatigue alarm conditions is fulfilled, the other alarm levels conditions are verified.

Moreover, despite not being considered in this experience, the algorithm can analyze the continuous bad status and a possible death condition (alarm 9). Additionally, it calculates the longest continuous time in which the subject presents a maximal effort status. Furthermore, it generates assessments in two additional levels. In the second level of examination, data is resampled to an hour frequency and, sustained fatigue alarm levels and related percentages per day are calculated. Finally, the third level of analysis is presented with mean values per day. All these generated assessments are also exported to the previously referred Excel file.

Table 2 Alert alarm levels

Alarm codes	Alarm level	Interpretation
1	Overall status: good	Recorded values within the reference range
2	Low intensity fatigue	Recorded values within the reference range but with significant elevations in any parameter
3	Moderate intensity	Minor fatigue detected
4	High intensity	Significant increases in recorded values. Intense training scenario
5	Maximal effort	Values near or on the limit of the maximum permissible. Maximum intensity training
6	Overall status: bad	Recorded values under or above the reference range. High risk health scenario
7	Faint	Potential faint based on recorded values and body position
8	Totally absent	Null values detected
−1	Sensor not working	The sensor is not functioning correctly. Reliability of recorded values compromised

3.1 Physiological Variables

Heart rate. Consulted literature in both, high intensity training scenarios [6–8] and military settings [9–11], revealed the strong relationship, independent of age and sports discipline, between exercise intensity and the different HR-derived variables. As a result, first filters were determined through this parameter. However, since cardiac reactivity can vary significantly from one individual to another, and baseline measurements can also be diverse, fixed values of HR were not determined, as they would not be representative for all scenarios. Alternatively, it was found that variations of HR expressed as percentages of the subject's theoretical maximal HR allowed a more accurate categorization on the intensity of physical activity [12–14]. Thus they were selected as the primary premises for the four established fatigue alarm levels.

Core temperature. Along with HR, literature from previous investigations [10, 11, 15–17] and normative guidelines [18] have proved the relevance of correlating the abovementioned with T_{co}. Referring to normative ranges [18], thermal strain evidences through values from 38 to 39 °C. However, during high intensity training, studies have shown that upper limits go above 39 °C [17]. As a result, fatigue alarms were set considering ranges from 38 °C, for low intensity fatigue, to above 39 °C, when the maximal effort is reached. Additionally, cases of potential hypothermia were covered by taking as a reference the cited ISO norm and values for occupational settings [18, 19]. This last source also served to characterize cases of potential faint (alarm 7).

Breathing rate. Additional conditions were included with respiratory frequency references. Even though literature provides limited evidence of this parameter as a training measure, studies have shown it is currently measured as a vital sign by multiparameter wearable devices in the military field, clinical settings, and occupational activities [20]. What is more, it has been proven to be strongly associated with RPE during a variety of exercise paradigms [21, 22], and under several experimental interventions, which suggests this variable is indeed a reliable marker of physical effort. Furthermore, unlike other physiological variables, it can respond rapidly to variations in workload during high-intensity interval training, with potentially significant implications for many sporting activities [20]. For this alert-based system, similarly to HR, breathing rate (BR) limits were established as percentages of the subject's maximal respiratory frequency and taking as a reference the categories provided by a previous investigation [21] from its proven correlation with RPE.

4 Results and Discussion

In total, data from 5 subjects were referred for assessment. Using the algorithm, it was possible to evidence fatigue evolution during the designed up-to-exhaustion exercise. In this regard, similar tendencies were observed among participants, as they gradually went from a first alert level (at the beginning of the trial) to high-intensity fatigue (alarm 4) at the end. Furthermore, when considering results from RPE, they evidenced the expected increasing tendency of values in all subjects. What is more, when correlating both outcomes; alert alarms with the obtained values of RPE (Fig. 1), comparable growing trends were detected. Moreover, observing the correlation coefficient (r) obtained in each case, the strong positive linear relation between them was proven.

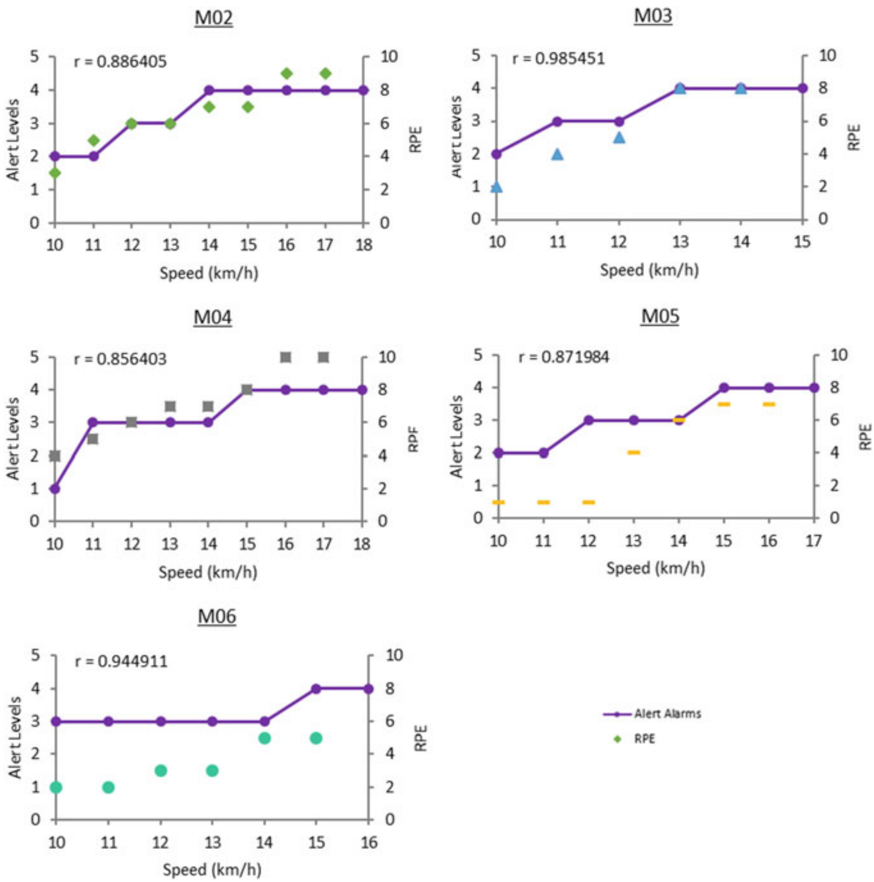

Fig. 1 Algorithm-generated Alert Alarms versus RPE

Given the characteristics of the experimental protocol, in which speed was gradually increasing every minute until perceived exhaustion, evidenced patterns proved to be accurate and representative of the assessed scenario. Since the exercise was short, performed in controlled climatic conditions and subjects were physically active, it was anticipated that fatigue levels were going to be present, but extreme conditions of maximal effort or a bad overall status were not going to be registered. Consistently, alert alarms gradually increased along the exercise and reached a high-intensity level (alarm 4) at the end of the experience in all cases.

On the other hand, from an individual perspective, some observations could also be described. M06 registered the highest time in fatigue levels 3 and 4 and was the only one evidencing intermittent changes between levels 1 and 2 at the initial phase of the exercise. When referring to his anthropometric characteristics, all these patterns were justified as the subject, alike the other four, evidenced an overweight condition, which helped to infer he did not have a physical condition as good as the other subjects. In contrast, M03 evidenced the best physiological response, as he presented the shortest period between levels 3 and 4. Furthermore, M04 showed the most stable tendency from all participants, as he underwent each stage of fatigue for similar periods of time. This fact was justified as he indicated to be a professional marathoner and therefore, potentially in better physical condition than the rest of the participants.

However, despite the proven applicability of the proposed algorithm, certain limitations were encountered. The algorithm proved to be successful in its minute-by-minute analysis and provided reliable results in short incremental practices but, additional levels of assessment were not validated within the trials and analysis of sustained alert levels over time, essential to verify impaired health status, could not be performed. Furthermore, even though alarms consider an integration of various physiological parameters, literature evidences that other variables such as T_{sk} and accelerometery counts, which are also recorded by physiological monitoring systems, are able to provide additional information on the impact of physically demanding activities [23–25], and their inclusion not only would have supported the reliability of developed analysis, but would have permitted a maximization in the utilization of the equipment's features.

Consequently, this algorithm constitutes a first approach in which improvements and validations within more significant samples, and considering all levels of assessment, can be made to enable not just retrospective but also continuous and real time assessments. Finally, another opportunity for improvement was found regarding how variables are treated, since physiological responses can differ considerably among individuals and measured values can also be diverse, recent studies have proved that variations of recorded parameters, such as T_{co} [26, 27], are more sensitive to changes than directly recorded values. Thus, the possibility of this approach should also be evaluated.

Lastly, referring to its applicability, the algorithm from this study is not computationally complex and has the potential to be executed by the on-board processors present in many wearable devices with minor modifications. What is more, utilizing this approach, additional sensors and measurements can be integrated into wearable and connected devices, creating novel comprehensive remote monitoring systems. Lastly, assessment methodology included in this algorithm could be the first step towards developing a real time monitoring system that enables immediate assessments and provides continuous updates on the subject's health status, which would have a wide applicability in safety sensitive professions such as soldiers in the battlefield.

5 Conclusions

In conclusion, the validation and applicability of an assessment algorithm for fatigue detection and management, within laboratory conditions, are reported. Based on obtained results, it was demonstrated that this alert-based system was able to provide reliable outcomes and led to the successful identification of the most physically demanding periods and their direct impact on physiological parameters. Overall, by providing a systematic and multivariate approach, it is believed that this assessment method, with further modifications, has the potential to improve fatigue management, allowing early detection of potential physical impairments, reducing the number of medical evaluations performed and minimising unnecessary delays in treatment.

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Real Time Fatigue Assessment: A Short Review Evidencing the Usage of Safety Monitoring Systems with Military Enforcement

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Abstract Fatigue decreases performance and physical strength causing incidents and accidents in operational settings. During military operations, soldiers encounter extreme conditions, which combined lead to a fatigue status that can cause serious physiological impairments, decreasing performance on the battlefield. Comprehensive studies in realistically stressful environments are essential to expand the knowledge regarding the consequences of real-life stress exposure and facilitate the development of operationally-useful techniques. This review, as part of a project for the development of a safety system based on physiological monitoring, aims to obtain relevant information about fatigue assessment through multiple physiological parameters in the military context, to focus on determining the associations between fatigue and physiological response in order to plan adequate interventions to prevent related negative consequences. Five databases (Scopus, PubMed, Science Direct, Medline and Web of Science) are used to develop a data search based on the crosswords of keywords. A total of 12 publications are included in the review. Topics such as sample characteristics, assessment context, purposes and findings of each study, parameters and equipment used, are analyzed.

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Keywords Fatigue · Physiological monitoring · Military performance

1 Introduction

Fatigue is a complex and multifaceted phenomenon. In general, it can be understood as a condition involving the decreased ability of individuals to perform activities at the desired level due to lassitude or exhaustion of mental and physical strength [1, 2]. Fatigue degrades performance and well-being leading to error, incident, and accident in operational settings. An operational setting is one in which effective human performance is crucial to a successful outcome. If the human fails, the system fails. Technological advances are enabling 24/7 operations and the integration of human activity around the globe, thus increasing exposure to the factors creating fatigue [3].

Military operations are not exempt from this. In fact, the physical demands of combat impose unique stresses on soldiers completely different from civilian occupations. Besides typical operational stressors, soldiers are exposed to extreme environments, heavy workload, inadequate sleep, information overload, dehydration, and impaired nutritional status. The combination of these stressors can cause serious physiological impairments, decreasing performance on the battlefield [4, 5].

As physiological stressors compromise health and performance, human performance optimization involves strategies to sustain both in the face of these stressors. Physiological modeling defining human tolerance limits and the effect of moderating factors provides scientifically based strategies to interventions that ultimately involve the way individuals and teams eat, rest, train, and are equipped. Thus, it is important to consider models that combine multiple stressors because individuals are rarely subjected to only one stressor at a time [6]. Additionally, comprehensive studies in realistically stressful environments are essential to expand the knowledge regarding the consequences of real-life stress exposure, facilitate the development of operationally-useful techniques and promote the conception of improved treatments as they differ greatly from more controlled settings regarding the environment, activity, equipment, and subject motivation [7]. However, collecting the necessary physiological data in mission environments has historically been hindered by lack of access to in-theater warfighters and difficulties associated with measuring parameters such as heart rate (HR) and core temperature (T_{co}) in the field. It is only with the development of non-invasive physiological status monitoring (PSM) systems that such data can be collected effectively during military activities.

Therefore, the main objective of this systematic review is the search of relevant information about fatigue assessment through multiple physiological parameters in the military context, to focus on determining the associations between fatigue and physiological response to plan in the future adequate interventions to prevent related negative consequences.

2 Method

This systematic review was conducted following criteria outlined on The Preferred Reporting Items for Systematic reviews and Meta-Analyses Statement [8]. In this respect, a previous protocol [9] was elaborated to present adequate guidelines to develop research that can provide relevant results.

3 Results and Discussion

3.1 General Results

The first identified articles (10.204) were reduced to 12 significant publications. Figure 1 displays the flowchart of the systematic review stages. All selected articles have written informed consent; assessment applied to human subjects and a committee ethics approval. Summary data are presented in Table 1. From this group, five are related to studies developed in the United States of America [10–14], two come from France [15, 16]; other two are from Finland [17, 18], one from Poland [19] and one from Switzerland [20].

Fig. 1 Systematic review stages

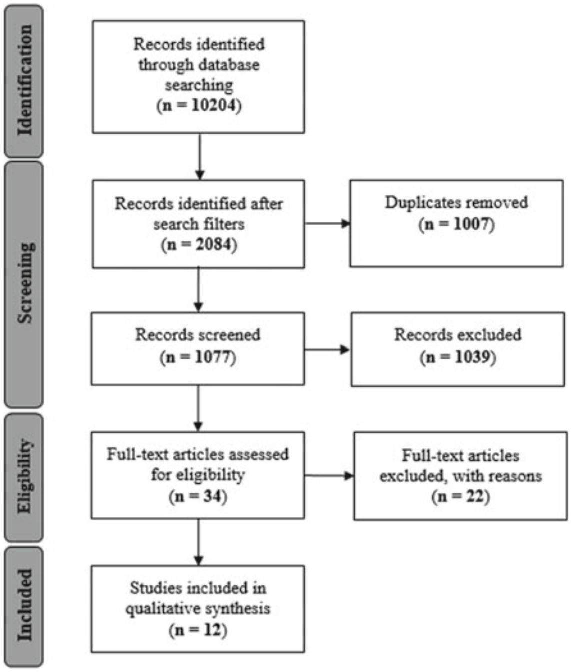

Table 1 Summary of included studies

Reference	Sample characteristics	Related parameters	Related physiological monitoring equipment
Lieberman et al. [10]	60 males Age: 21–34 years	HR	EquiVital type 1 Sensor electronics module (SEM) (Hidalgo Ltd., Cambridge, UK)
Ralph et al. [21]	35 males, 1 female Age: 23–45 years	PA	Wrist actigraph (Ambulatory Monitoring, Inc., Ardsley, NY)
Charlot et al. [15]	60 in two groups: no training (age 24.3 ± 3.6) and training (age 24.3 ± 3.9)	HR, T_{co}	Chest belt and HR monitor wrist receptor (RC3 GPS, Polar, Kempele, Finland). Electric thermometers (PX-TH 418, Pelimex, Ingwiller, France)
Buller et al. [11]	27: 25 males and 2 females Age: 29.9 ± 6.4	HR, T_{co}	Chest belt PSM (Equivital EQ-02, Hidalgo Ltd., Cambridge, UK) Thermometer pills (Jonah Core Temperature Pill, MiniMitter, Respironics, Philips, Bend, OR)
Simpson et al. [12]	144 recruits from Fort Jackson and 120 from Fort Sill	PA	ActiGraph GT3X triaxial accelerometer (ActiGraph, LLC, Pensacola, FL). PAtracker
Redmond et al. [13]	144 recruits from Fort Jackson and 120 from Fort Sill	PA	ActiGraph GT3X triaxial accelerometer (ActiGraph, LLC, Pensacola, FL). PAtracker
Jouvion et al. [16]	40 subjects (38 males, age 28.4 ± 4.9 years) with a history of EHS	HR, T_{co}	Ingestible temperature sensor (Cortemp HQ Inc., Palmetto, Florida). Chest belt (T31 Polar transmitter, Polar Electro, Kempele, Finland)
Pihlainen et al. [17]	79 male soldiers Age: 29.8 ± 8.0	HR and PA	Recordable memory belt (Memory belt, Suunto, Vantaa, Finland) Tri-axial accelerometer (Hookie AM20, Traxmeet, Espoo, Finland)
Tomczak et al. [19]	15 air force cadets Age: 19.6 ± 0.3	HR	Not provided information
Welles et al. [14]	10 male marines Age: 21.9 ± 2.3	HR, T_{co}, PA	Equivital EQ-01 (Hidalgo, Cambridge, United Kingdom). Thermometer pills (Mini Mitter; Bend, OR)
Wyss et al. [20]	1676 for injury data and 50 from each of 12 Swiss Army Schools for sensor data Age: 20.7 ± 1.2	HR, PA	HR monitors (Suunto Smartbelt and Comfortbelt; Suunto, Vantaa, Finland). Step and acceleration monitors (GT1M [ActiGraph LLC, Fort Walton Beach, Florida] and PARTwear [HuCE microLab, Biel, Switzerland])
Pihlainen et al. [18]	15 male conscripts. Age: 19.4 ± 1.1	HR	HR monitors (Polar S610, Polar Electro, Kempele, Finland; Suunto t6, Suunto, Finland)

The 12 articles included in total 2546 participants, of which approximately 2453 were men and 93 women (estimations were made for one sample used in two studies [12, 13] that did not provide specific gender numbers), representing 96.3 and 3.7%, respectively. Ages ranged from 19.4 to 29.9 years old. Participants were healthy active military personnel except those from one study that developed an investigation with military subjects who had a history of Exertional Heat Stroke (EHS) [16]. Among them, only one had a control group of non-training soldiers [15], whereas the rest used comparisons with previous or basal levels of the same soldiers.

As one of the selection criteria established the inclusion of studies developed in field, combat or training military context, it could be observed that 8 took part during different training activities (Captivity Survival; Chemical, Biological, Radiological, Nuclear, and Explosive materials defense—CBRNE, Basic Combat, and Basic Physical training) [10–13, 16, 19–21], 3 were applied during operations [14, 17, 18] and 1 considered both scenarios [15]. Taking into consideration assessed parameters through non-invasive measurements, most of the studies evaluated HR (9 studies) [10, 11, 14–20], while 6 monitored physical activity (PA) [12–14, 17, 20, 21]. Additionally, it was found that three studies, besides considering at least one of the mentioned parameters, also developed T_{co} measurements [14–16].

Comparing assessment equipment, 3 of them used an EquiVital physiological monitoring system with ingestible thermometer pills [10, 11, 14], 4 used actigraphs [12, 13, 17, 21] (2 of them simultaneously using PAtrackers) to record physical activity (PA) and 5 utilized different chest belts and HR monitors [15–18, 20].

On the other hand, included studies also involved other assessment approaches that even though are not the primary focus of this review, are relevant to support the analysis of results from the previous indicators. Evaluation of stress markers in saliva and blood samples such as cortisol, epinephrine, norepinephrine, neuropeptide-Y (NPY), dehydroepiandrosterone-sulfate (DHEA-s), prolactin, lactate, and testosterone were included in 3 studies. Cognitive performance was assessed in 2 studies through the application of tests: Psychomotor Vigilance Test (PVT), Match-to-Sample, Grammatical Reasoning, and N-Back. Rates of perceived exertion (RPE), maximal oxygen uptake (VO_2) and environmental conditions were part of three investigations each, and mood states were monitored in one study.

3.2 Studies Outcomes

As it was mentioned, three publications included EquiVital equipment for respective investigation [10, 11, 14]. One developed a multi-dimensional assessment during a simulated captivity training that took place at the military Survival, Evasion, Resistance, and Escape (SERE) School and involved an academic phase, a stressful field survival training and a captivity simulation. Results demonstrated significant increases during the two mock interrogation parts of the captivity phase;

HR increased 42% from baseline during the first interrogation and 81% in the second. From this investigation, the main outcome was the evidence of the simultaneously altered parameters during the simulated captivity in all measured dimensions, as increases in HR were consistent with elevations in epinephrine and norepinephrine, and decrements in mood states, degraded cognitive function, and substantial body loss were also evidenced during this phase. Alternatively, the other two studies [11, 14] had a different approach, as they were evaluating situations with possible heat strain of the participants. Both measured HR and T_{co} and evidenced that despite ambient limitations, reliable measurements can be obtained in field situations.

Using different monitoring equipment, two French studies [15, 16] also developed HR and T_{co} assessments. One of them [15] evidenced that low volume physical training improves heat acclimatization as it enhances decreases in HR, sweat loss and osmolality, and in subjective measures such as RPE and general thermal discomfort, but concluded that it is not significant to influence rectal T_{co}. On the other hand, performing an 8 km-run in full combat gear, the second study [16] was not able to obtain conclusive results, as the observed increase of 0.5 °C in T_{co} in the last 10 min of running was not sufficient to determine it as a risk indicator for EHS recurrence.

HR was also combined with PA in two publications [17, 20]. Both used HR monitors and triaxial accelerometers but in different contexts. One of them [20], investigated the impact of different physical training patterns on the incidences of injuries by monitoring PA, training demands and HR. It concluded that high physical demands, decreasing distances covered on foot, low monotony, little time spent in sport-related PT, and little time for night rest were significant risk factors for injuries, as they were responsible for the majority of them within the studied military population. In contrast, the other publication [17], while assessing the same parameters along with stress biomarkers and RPE, was not able to get significant results due to the operatively calm nature of the working environment, which was corroborated by the observed light physical overload and low HR responses.

PA was also evaluated in three studies [12, 13, 21]. Two [12, 13] were developed with the same sample from two US Basic Combat Training sites while the third [21] took place during a captivity survival course. Referring to the first two, one compared the activity from both sites by using instrumentation with an accelerometer, direct observation with a PAtracker and daily PA logs while the other compared these three methods to determine the agreement among their measurement. Both studies were able to prove the reliability of results from the three methods as outcomes were congruent among them and concluded that, the actigraph gave the best measure of the recruits' PA intensity while the PAtracker and daily PA log were best for capturing body position and type of PA. Lastly, the third cited publication [21], having as a main objective the assessment of psychological functioning and neurohormones, also monitored sleep, rest and activity periods based on actigraphy data. The goal was to quantify the effects of the Conduct After Capture (CAC) training, which program and phases (Didactic, Practical and Recovery/debriefing) resemble some core features of the survival course of SERE school, analyzed in a previous study [10]. Interestingly, despite the different sample characteristics and program duration (4 days vs. 3 weeks), the investigation demonstrated that measures were mostly degraded with training, especially during the more intense interrogation, similar to what was concluded by the other study. Nevertheless, inconsistency between results was found in the analysis of cognitive performance, as CAC training did not show an effect on short-term memory as SERE training observed.

From the twelve publications, some conclusions could be gathered. First, it was proved that reliable measures could be collected in training activities and during in-theater missions [11, 14]. Secondly, two studies [10, 21] concluded that physical and psychological demands of simulated captivity survival training could simultaneously alter physiological functioning, stress hormones levels and most variables related to cognitive performance, as only short-term memory presented different outcomes between both investigations. Correspondingly, one study [19] determined that 36 h of survival training without the possibility of sleep affected coordination performance but did not influence short-term concentration. Lastly, when it comes to methods for measuring PA patterns, it was demonstrated within two publications [12, 13] that actigraph provides the most accurate data of PA intensity and other methods such as PA tracker and PA logs are better for reporting body position and type of PA. In general, it was observed that publications enhance the assessment of stressors impact by physiological measuring in the face of other evaluation methods because it avoids the time consuming and labor intensive of in situ observations and provides more reliable results than the use of subjective self-report questionnaires [20]. Additionally, the importance of collecting multiple variables is highlighted to obtain a complete characterization of the effects of fatigue on physiological functioning.

Finally, some general limitations were found, mainly related to the anticipated difficulties of measurements in field situations. Most presented differences in the number of subjects completing each test and some indicated that not all soldiers were able to complete all parts of the training programs. Additionally, two studies [11, 14] did not have the same subjects for each training event to compare performances between the different scenarios. In most, if a large number of volunteers would have been recruited, more robust effects may have been observed [21]. Moreover, problems ensuring the proper functioning of the monitoring systems were reported in one study.

Furthermore, it was not always possible to continuously monitor all considered parameters, which could have given a complete view of results. Also, only one study had a control group, and in investigations like the assessment of soldiers with a history of EHS, comparisons between groups would have given a clearer perspective of obtained results. Finally, samples consisted primarily of men. Although it represents what is typically observed in the military context, caution must be exercised in drawing inferences and making generalizations to both genders [21].

4 Conclusions

Included articles demonstrated that physiological parameters such as HR, PA and T_{co} can be good predictors of fatigue, as they present corresponding alterations when submitted to environmental, metabolic and neuropsychiatric stressors. Additionally, and despite encountered limitations, this review was able to prove that reliable data can be collected in field situations. Furthermore, since only three studies included simultaneous assessment of physiological variables with the use of a non-invasive PSM such as EquiVital (the three with different approaches and considering diverse complementary variables) it can be concluded that there is a future research possibility by using this equipment to assess fatigue. This way, a multivariable assessment method can be executed, and supported fatigue measurements can be obtained in several military activities and within any occupational context. Finally, when referring to the assessment and analysis of obtained data, it could be evidenced that there is not a standard procedure or system to evaluate results and provide an interpretation regarding intervention levels to prevent health-related negative consequences. Thus, future perspectives can be focused on the establishment of this kind of system with applicability not only to the military but any safety-sensitive profession.

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Real Time Fatigue Assessment: A Short Review Evidencing the Relevance of Physiological Monitoring

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Abstract Fatigue decreases performance and physical strength causing incidents and accidents in operational settings. During military operations, soldiers encounter extreme situations, which combined lead to a fatigue status that can later develop in overreaching (OR) and overtraining (OT) conditions. Studies in real environments are essential to expand the knowledge regarding the consequences of stress exposure and facilitate development of operationally-useful techniques. Nevertheless, there is not much available information on non-invasive physiological monitoring during high training military activities. Therefore, this systematic review, as part of a project for the development of a safety system based on physiological monitoring, aims to evidence the relevance of non-invasive physiological monitoring for detecting stages of fatigue, OR, OT and indicators of potential physical impairments in high intensity training scenarios. Four databases (SCOPUS, PubMed, Medline and Science Direct) are used to develop a data search based on the combinations of keywords. 19 articles are included in this review. Sample characteristics, assessment context, purposes and outcomes of each study, were analyzed. Conclusions regarding the most suitable parameters to be considered within an occupational safety assessment system, applicable to military operational settings, were gathered.

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Keywords Fatigue · Physiological monitoring · Military performance

1 Introduction

Fatigue decreases ability of individuals to perform activities at the desired level due to lassitude or exhaustion of mental and physical strength [1]. All athletes, in any sport, must train hard in order to improve, and they experience fatigue as a consequence of the regular training process [2]. When the balance between training stress and recovery is disproportionate, it is thought that overreaching (OR) and overtraining(OT) may develop [2]. OR occurs when the restoration of performance capacity takes from days to weeks. If performance recovery takes from weeks to months, a state of OT may have been developed [3]. Nevertheless, cases of OT or OR can occur in response to demanding training loads in all population groups, not just athletes. Symptoms of OT have been documented during military training in many countries, including the United States, Spain, and Norway and, these symptoms are more likely to develop when training is combined with other stressors, such as psychological stress and inadequate nutrition [4]. In this regard, it can be highlighted that besides typical operational stressors, soldiers are exposed to extreme environments, heavy workload, inadequate sleep, dehydration and impaired nutritional status. The combination of these stressors can cause severe physiological impairments, decreasing performance on the battlefield. Thus, comprehensive studies in realistically stressful environments are essential to expand knowledge regarding the consequences of real-life stress exposure, facilitate the development of operationally-useful techniques and promote the conception of improved treatments [5].

Nevertheless, there is not much evidence of non-invasive physiological monitoring during high intensity military training [6]. Therefore, a systematic review is proposed to evidence the relevance of non-invasive physiological monitoring for detecting stages of fatigue, OR and/or OT that would allow early detection of pathological conditions in high intensity training scenarios and could be applied to a military context or any other occupational setting.

2 Method

This systematic review was conducted in accordance with The Preferred Reporting Items for Systematic reviews and Meta-Analyses PRISMA Statement [7]. The applied criteria are presented in Table 1.

Table 1 Criteria applied in the systematic review stages

Stage	Criteria
Search strategy	Initially, a series of keywords were defined. In general, they referred to physiological monitoring, training stages, overreaching, physiological variables and risks associated with high intensity training. As a result, 21 combinations were formed. To test the relevance of their findings, a first search was conducted using the Scopus database. Combinations were filtered as many of them presented results unrelated to the topics outlined in this work. Finally, the combinations defined to conduct the review were formed by the following two groups of keywords: group (A) with 'physiological monitoring', 'physiological measurement' and 'life monitoring' and group (B) with 'fatigue', overreaching' and 'overtraining'. The search was developed through 4 databases: Scopus, PubMed, Medline and Science Direct, and based on 9 combinations of keywords
Screening criteria	The search was initially conducted by inserting each combination and selecting, when possible, "Article title, Abstract, Keywords" (Scopus, Science Direct and Medline). All fields were considered in PubMed Three phases were applied in this process. An initial phase of exclusion was implemented through the search filters of the databases. The first criteria were "Type of Article": only Articles and Articles in Press were filtered. Additionally, only Journals were chosen when applying the "Source Type" filter. Next, all articles but those written in English were excluded. Finally, articles from journals related to Physiology, Sports, Medicine, Ergonomics, Health and Fitness were delimitated with the "Source Title" filter. No date restrictions were considered to collect all available information in the area Lastly, the third phase followed this procedure: (a) Title and abstract were analyzed: Studies were automatically excluded if one of these conditions were met: (1) studies were not developed in high intensity training context; (2) studies involved only subjective methods of assessment. (b) The full-text article was retrieved: Whenever the title and abstract did not provide enough information to determine if the selection criteria were met, the article went through this step
Eligibility criteria	Articles were included if all the following conditions were met: (1) they were applied on male samples (mean age over 18) with standard anthropometric characteristics, including average height and weight and normal IMC; (2) subjects were regularly physically active; (3) they evidenced a representative sample size, case studies were not considered, and (4) they included a non-invasive physiological assessment method

3 Results and Discussion

3.1 General Results

The first identified articles (5513 from Scopus, 2302 from PubMed, 74 from Medline and 2066 from Science Direct) were reduced to 19 final publications. Figure 1 displays the flowchart of the systematic review stages. The 19 articles have written informed consent, assessment applied to human subjects and a committee

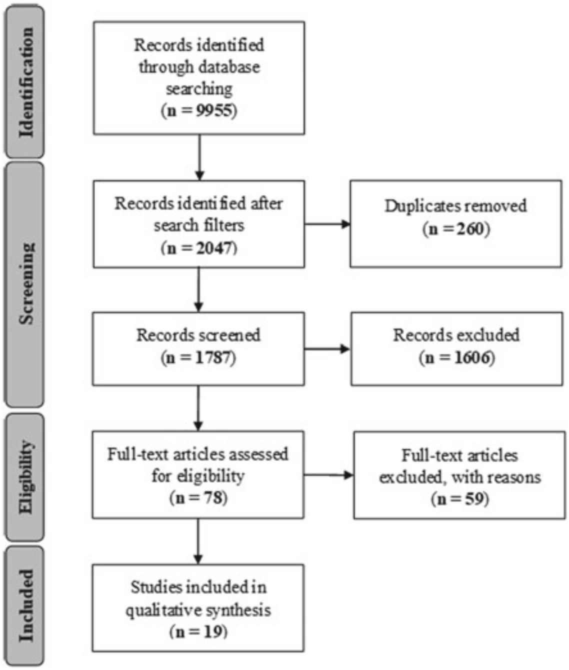

Fig. 1 Systematic review stages

ethics approval. They included in total 385 male participants. Ages ranged from 18.5 to 36.6 years old. Summary data of selected publications are presented in Table 2.

As one of the selection criteria stablished the inclusion of studies in which the participants were regularly physically active, it was possible to identify athletes from a variety of sports disciplines; triathletes took part in three studies and soccer players were considered in other three. Long distance runners, water polo players, football players, cyclists, road-race motorcyclists, handball field players, trail runners, wrestlers, futsal players, rugby union players and bowlers were also identified. Furthermore, two investigations were developed with military personnel [8, 9]. All studies indicated subjects were involved in regular physical training programs. However, six did not provide details on the average weekly training time or the subjects' experience on the disciplines. Among them, three had control groups [10–12], whereas the rest used comparisons with previous or basal levels of the same participants.

Taking into consideration assessed parameters through non-invasive methods, 16 studies evaluated heart rate (HR) [9–23] while 3 focused on activity patterns [8, 24, 25] and one included both assessments [12]. Only one investigation, at the time of recording HR changes, monitored core and skin temperature (T_{co} and T_{sk}) [26]. Likewise, respiratory patterns were considered within one study [14].

Table 2 Summary of included studies

Reference/country	Assessed parameters
Saboul et al. [13]/France	HR (HRV*, HR_{rest}*, HR_{max}*), RPE
Galy et al. [14]/Tunisia	HR, VO_{2max}*, $Th1_{vent}$*, $Th2_{vent}$*
Buchheit et al. [15]/ Australia	HR (HR_{ex}*, LnSD1*, post-exercise HRV). PV, TL, perceived ratings of wellness, salivary cortisol
Le Meur et al. [10]/ France	HR, lactatemia, VO_2*, VE*, biomechanical parameters (CK*, plasma epinephrine, norepinephrine), RPE, kinetic and kinematic measures, cognitive performance
Lamberts et al. [16]/ South Africa	HR (beats/min, HRR), VO_{2max}, speed (km/h), power output (W), cadence rpm
D'Artibale, et al. [17]/ Italy	HR (%HR_{max}), blood lactate
Coutts et al. [11]/ Australia	HR, VO_{2max}, VO_2, lactate threshold velocity, blood lactate concentration, RPE, psychological measures
Michalsik et al. [18]/ Denmark	HR, VO_{2max}, relative workload (RWL), blood lactate concentration, fluid loss, maximal aerobic capacity, maximal muscle strength, physical profiles
Easthope et al. [19]/ France	HR, running time, lactate concentration, RPE. Maximal voluntary contraction torque (MVC), counter movement jump height (CMJ), plasma creatine kinase (CK) activity, muscle soreness
Tomczak et al. [8]/Poland	Tremor measurements by acceleration
Bendiksen et al. [20]/ Denmark	HR(%HR_{max}), VO_{2max}, recovery plasma creatine kinase, muscle glycogen, muscle CrP, sprint velocity, blood lactate, blood glucose, technical performance
Barbas et al. [21]/Greece	HR (%HR_{max}), lactate, hormonal and metabolite functions. Performance: vertical jumping, hip-back strength. Muscle damage: CK activity, DOMS, and joints' range of motion. Inflammatory response: C-reactive protein, leukocyte counts, IL-6, oxidative stress
Vaananen [9]/Finland	HR (bpm, %HR_{max}), perceived pains, functional capacity of lower extremities (flexibility, functional strength, use of elastic energy and oedemic changes). CK, cortisol, testosterone, luteinizing [27] and follicle stimulating hormone (FSH). Mood states
Krustrup et al. [22]/ Denmark	HR, lactate, muscle crP, glycogen, pH
Nakamura et al. [23]/ Brazil	HR (HRV: In $RMSSD_{Weekly}$, In $RMSSD_{CV}$), RPE
Hausswirth et al. [12]/ France	HR, sleep patterns, maximal aerobic power, VO_{2max}, blood lactate, mood states, incidences of illness, RPE
Shearer et al. [24]/United Kingdom	Sleep patterns: time in bed, sleep latency, time asleep, time awake, sleep efficiency, actual sleep percentage, the percentage of time moving, and sleep restlessness
Robey et al. [25]/ Australia	Sleep measures (bedtime, wake time, sleep duration, sleep onset latency, sleep efficiency). RPE, fatigue, recovery
Minett et al. [26]/ Australia	HR, T_{co}, T_{sk}, sweat loss. Performance: ball speed, accuracy and run-up speeds. Physical: GPS monitoring, and counter-movement jump height. Biochemical: serum concentrations of damage, stress and inflammation. Perceptual: RPE and thermal sensation

3.2 Studies Outcomes

As mentioned, two studies were developed with military personnel [8, 9]. One of them [9], examining army officers, cadets and recreational endurance athletes, evidenced the strong relationship between physical training intensity and $\%HR_{max}$ (percentage of maximum HR). The second [8], considering 36 h of survival training with sleep deprivation, showed that along previously mentioned alterations, increasing fatigue and lack of sleep influenced psychomotor performance.

Considering diverse sports disciplines, three more studies [13, 15, 23] developed HR assessments but focused on heart rate variability (HRV). What is more, one of them [13] established as its primary goal the validation of a HRV index to assess training load (TL) in field conditions. This work evidenced that HRV was strongly correlated with exercise intensity within a long-distance runners' sample, and the proposed index provided correspondent results with other applied methods. On the other hand, a second study [15] examined HR_{ex} (exercise HR) and post-exercise HRV along with other physiological and perceptual measures. As a result, these HR-derived measures, TL and wellness measures were proved to be the best simple parameters for monitoring intensified training responses. Moreover, by evaluating two HRV variables, during a professional futsal preseason, it was possible to conclude that monitoring HRV on an individual basis was useful to detect players deviating from expected responses to training [23].

Additionally, similar to formerly referred publications [9, 20], three articles [17, 19, 21] determined the intensity of efforts from HR recordings expressed as a percentage of the participant's maximal HR ($\%HR_{max}$). In general, they demonstrated the adequacy of this variable to evidence the high loads on participants [17] and the significant demands of competitive scenarios [19, 21]. Additionally, and despite covering a variety of physical activities, percentages showed comparable results between all, as they evidenced from 85% during a simulated wrestling tournament [21], 86% through a simulated soccer game [20], 87% during skiing [9] and approximately 90% in both, field-based trail running [19] and road-races of motorcycling competitions [17].

Correspondingly, another study [14] considered $\%HR_{max}$ along with HR_{rest} but with the aim of determining $HR_{Reserve}$, which is the difference between them. Within this investigation, $HR_{Reserve}$ was found to be significantly correlated with players' VO_{2max}, indicating that physical intensity was influenced by the player's aerobic capacity. Finally, among all studies, only one [26] considered HR recordings along with T_{co} and T_{sk}. In this respect, while examining physiological and performance effects of pre-cooling on medium-fast bowling in the heat, it was able to demonstrate the unique physical requirements of cricket fast-bowling and, proved the thermoregulatory control improvement obtained with pre-cooling, validating the suitability of HR, T_{sk}, T_{co}, sweat loss and RPE to monitor physiological responses to training.

From the 19 articles, some assumptions could be gathered. First, it was proved that reliable measures could be collected not only in laboratory but also in field situations. Furthermore, outcomes revealed that performance is multidimensional [14], thus, monitoring various parameters is required to have a better perspective of responses to high physical demands and contextual stressors [10]. What is more, the importance of identifying early markers of fatigue, OR and OT, is highlighted to limit the occurrence of these training maladaptation forms in the population at risk [10]. On the other hand, it is important to mention that observed large standard deviations of some outcomes indicates that significant inter-individual differences exist within a sample, which leads to the idea that information should be analyzed in an individual basis. Furthermore, since it was observed that mean values of some results were compromised compared with population norms, it can also be emphasized the need of assessment models in which reference values are delimitated according to the population context to which they are intended. Lastly, when selecting assessment parameters, it can be stated that HR and its derived measures are appropriate, as they demonstrated to be good indicators of exercise intensity. Particularly, $\%HR_{max}$ evidenced its accuracy to identify the different phases of physical training and the high demands of specific disciplines. In this regard, HR expressed as $\%HR_{Reserve}$ also proved to be suitable for training contexts as it correlated with VO_{2max} evidencing the influence of the player's aerobic capacity [14]. Likewise, other methods such as actigraphy, thermal response (T_{sk} and T_{co}) and respiratory frequency, despite the reduced found evidence, showed to be able to provide accurate data for monitoring physiological responses.

Finally, it should be noted that, among studies, some general limitations were found. Most of them presented differences in the number of subjects completing each test. Additionally, some studies reported difficulties to monitor all training events [23]. Correspondingly, one study indicated to have used different actigraphs within the sample, which could have altered the generalization of obtained data [25]. Analyzing studied subjects, only three investigations used a control group [10–12], which would have allowed to better comparisons and supported the reliability of results in all cases. Lastly, it was observed that some relevant information about samples was not provided and, even though it does not necessarily bias the outcomes, details about training background and regularity (provided only within six studies), ethnics and nutritional habits would have helped to a more accurate contextualization of the developed research and a better understanding of potential factors influencing adverse outcomes.

4 Conclusions

This review demonstrated that a multivariate approach is fundamental when assessing fatigue, OR, OT and any related condition during training activities. Additionally, results revealed the strong relationship, independent of age and sports discipline, between exercise intensity and HR-derived variables. As a result, this parameter marks a focus point for an assessment of fatigue in any context. Furthermore, and despite the reduced number of supporting investigations, respiratory variables, activity patterns, T_{co} and T_{sk} proved to be accurate parameters to assess response to intensified PA. Therefore, they all demonstrated their suitability to be applied within any fatigue assessment procedure. Lastly, it was evidenced that within considered studies, there is not a standard system to evaluate results and provide an interpretation regarding intervention levels to prevent health-related consequences. Thus, future perspectives can be focused on the establishment of this kind of system, considering referred variables, with applicability not only to the military but to any safety-sensitive profession.

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A Pilot Study on Energy Expenditure Estimation Through Decision Modelling

D. Bustos, A. P. Sposito, A. D. Lucena and J. C. Guedes

Abstract The generation of standardized equations for predicting energy expenditure, to be applied to every healthy individual, is still subject to research. The purpose of this study was to contribute to the development of a decision algorithm to estimate energy expenditure for its application over a wide range of physical activities. Ten participants (age 31.70 ± 4.19) performed a sequence of 12 activities chosen to represent basal, light and moderate intensities. During each trial, participants wore three Actigraph accelerometers on the wrist, hip and ankle, and oxygen consumption was simultaneously measured by a portable metabolic system. From a previously developed literature research, 32 equations were selected to estimate energy requirements. Calculations and values obtained from oximetry were compared. As a result, a decision model was elaborated based on the equations which demonstrated to provide more accurate results. Future studies should be developed to validate the proposed model within bigger samples.

Keywords Physical activity · Energy expenditure · Actigraphy

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1 Introduction

The accurate prediction of energy requirements for healthy individuals has many useful applications [1]. Various studies associated with energy expenditure have been conducted within different contexts. From the occupational perspective, it has also been proven of great utility for ergonomics, safety, and health of workers [2]. Among the most accurate measurement methods, and considered within gold standards, are the double-labeled water method and direct and indirect calorimetry by oxygen consumption rate [2, 3]. However, as direct measurements are complex, expensive and not suitable for field studies, several mathematical equations have been adopted as a major technique for assessing energy requirements [4]. Most of them, developed by mathematical regression methods, combine anthropometrics, physiological variables, and movement patterns and are accepted for predicting energy requirements over a wide variety of activities [2].

Nevertheless, there is no available information on which equation is the most suitable for every kind of activity. To this end, the purpose of this study is to test existing predictive equations within laboratory trials and, based on obtained results, to propose a decision model founded on the best estimations of measured energy requirements for its applicability over a variety of occupational activities.

2 Materials and Methods

Most of the experiments were performed at the Laboratory on Prevention of Occupational and Environmental Risks (PROA) at the Faculty of Engineering of the University of Porto, while the rest were executed at the Faculty facilities. The volunteers were fully informed of the details of the experimental procedures and were briefed on purpose, potential risks and benefits of the experiences. Written consent was read and signed by them prior to starting the trials.

2.1 Subjects

Ten participants volunteered for the study. Their physical characteristics are shown in Table 1.

2.2 Materials and Equipment

The experiments were mostly conducted in a climatic chamber (FITOCLIMA 25000EC20). Body composition was assessed using bioelectrical impedance

Table 1 Participants characteristics

	Total (n = 10)		Males (n = 5)		Females (n = 5)	
Variables	Mean	SD	Mean	SD	Mean	SD
Age (years)	31.70	4.19	33.00	4.74	30.40	3.58
Height (cm)	168.00	10.58	176.80	4.44	159.20	6.22
Weight (kg)	67.70	9.71	73.00	7.52	62.40	9.24
BMI (kg/m^2)	24.01	3.11	23.34	2.09	24.69	4.03
FFM (kg)	50.07	11.36	59.62	6.38	40.52	4.64

analysis (Body Composition Analyzer InBody230). Energy expenditure (EE) was measured from pulmonary gas exchange using a breath-by-breath portable gas analyzer (Cosmed K_4b^2, Rome, Italy). For recording activity patterns, participants wore three accelerometers (ActiGraph wGT3X-BT): on the right wrist, right hip and ankle.

Additionally, a Polar H7 Heart Rate Sensor was applied to measure cardiac activity. For physiological monitoring, an Equivital Sensor module chest belt was used to record heart rate, respiratory frequency, skin temperature, and movement by accelerometry. As a result, 1.8 kg were added to account for the additional weight of the devices.

2.3 Experimental Design

Before testing, participants had their height and weight measured (in light clothing, without shoes). Later, they performed various lifestyle and simulated working activities. Activities were chosen to test the multiple equations found in the literature at the time of verifying the relevance of the measurements for occupational settings. By their applicability, equations were classified for estimating basal and with movement (multitask and with displacement) activities. The designed sequence of activities and their respective classification are detailed in Table 2.

2.4 Data Analysis

Obtained data were processed by an algorithm developed using Pandas, a Python 3.6 library for data analysis and statistics. In general, this algorithm took the monitored data (from excel files) as input parameters. It synchronized the data according to the recordings from the K_4b^2. Later, it generated mean values for each

Table 2 Protocol of activities

Activity sequence	Description	Duration (min)	Type of activity
1	Lying	10	Basal
2	Sitting, doing computer work	5	Basal
3	Standing, playing with cards	5	Multitask
4	Standing, moving up and down a 2 kg-load, metronome: 40 bits/min	5	Multitask
5	Sitting, watching a video	5	Basal
6	Sweeping	5	Multitask
7	Sitting-standing 10 times	Free	Multitask
8	Sitting, watching a video	5	Basal
9	Moving plastic boxes with a 5 kg-load	5	Multitask
10	Moving plastic boxes with a 10-kg load	5	Multitask
11	Sitting, watching a video	5	Basal
12	Slow walking (from the lab to the stairs)	Free	Displacement

one of the 12 protocol activities, based on the time marks recorded by the aforementioned K_4b^2. Then, based on the type of activity (basal, movement with displacement or multitask) it calculated energy expenditure with the respective equations.

2.5 Literature Search and Filtering

A comprehensive search of the literature was performed with the aim of identifying all studies that predict energy expenditure, based on anthropometric data and actigraphy, and develop an investigation within healthy participants. Consulted databases included: Academic Search Complete, Scopus, Web of Science, Science Direct, PubMed, Francis and Taylor, and Medline.

Search terms were selected so that any publication, which finds a prediction model for energy expenditure, is included. Retrieved articles were reviewed in two steps. First, abstracts were reviewed and items not fitting were excluded. Then, the full-text for the remaining articles were obtained and analyzed to select the articles that included an equation based on the above criteria. In a parallel process, reference tracking helped to identify additional studies not retrieved through automated search.

3 Results and Discussion

3.1 Equations Categorization

From the referred literature search, initial 124 potential approaches were identified for application within this study. After retrieving and analysis, they were reduced to 32 relevant equations from 23 authors. Through this present work, those equations will be identified according to the author in which study they were applied. Following criteria outlined in every publication, they were classified within two main groups: 'Basal' and 'Movement'.

Basal. Under this category are all the equations established for predicting energy requirements for resting or basal activities. As a result, 18 equations from 15 authors were identified: Harris-Benedict [5], Owen [6, 7], Mifflin [1], Liu [8], Ganpule [9], FAO/WHO/ONU [10], Henry [11], Muller [12], Livingston [13], Korth [14], De Lorenzo [15], Yang [4], Wang [16], Roza [17] and Haaf and Weijs [18].

Movement. In this group, two types of activities are identified, those daily variable activities ('Multitask') and those involving 'Displacement'.

Multitask. Under this label are equations developed for application in several daily activities. 9 equations from 5 authors were included: Tabata [19], Swartz [20], Crouter [21], Pandolf [22] and Epstein [23].

Displacement. Within this group are the equations to be applied to rhythmic, locomotor physical activities, such as walking and running. This category is formed by the equations from the previous group and those developed exclusively for this kind of tasks: Freedson [24] and ACSM [25].

3.2 Experimental Results

Considering the differences between measured and predicted results, data revealed equations that better adapted to every activity in the protocol. Figure 1 shows mean measured values from all participants and the estimations that better approximate to the oximetry outcomes, individually analyzed.

Basal activities. When considering general results, most participants evidenced Korth's equation (based on weight, height, sex, and age) to be the one predicting values with a better approximation to K_4b^2, followed by the Haaf&Weijs' equation, based on fat-free mass (FFM). Notably, from individual analysis, Korth's equation proved to work well for men in most cases and poorly for women. Correspondingly, Haaf&Weijs equation gave better results for females. Despite all, they both were responsible for the majority of the most accurate results. What is more, for the cases in which different equations were identified, Korth and Haaf and Weijs equations, still appeared as the second best. As Korth et al. [14] anticipated, choosing the appropriate resting predictive equations should be based on the agreement of the

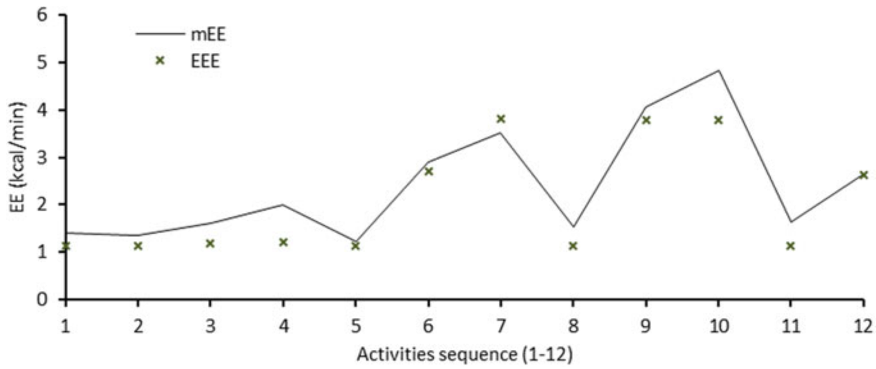

Fig. 1 Measured EE (mEE) versus estimated EE (EEE) per activity

study population and protocol with the characteristics of the reference population and study protocol used for generation of the equation. In that regard, it was observed that anthropometrics from Korth's study and only male participants from this study were comparable, which can explain why the equation worked well mostly for the male proportion of the sample. Nevertheless, from both equations, some general outcomes were revealed. Since FFM (included in Haaf and Weijs prediction) can be expressed by a function of age, sex, height, and bodyweight (variables of Korth's equation), both equations corroborated that the predictive power of body weight can be substantially improved by the inclusion of height, sex and age [14].

As a result, since body composition measurement is not always possible, the equation of Korth is advised for use in a young subjects' sample.

Multitask activities. In a general perspective, it could be observed that most multitask activities were better estimated regarding energy requirements, by the equations proposed by Swartz [20]. This author developed three equations in which calculations are made based on counts from two accelerometers (located on the wrist and hip) by separate and combined. Within this study, the applicability of the wrist and wrist-hip equations evidenced better outcomes.

On an individual basis, some other approaches also proved to provide good estimations. Specifically, in activities 3 and 4, an equation proposed by Crouter [21] evidenced better predictions (followed by Swartz equations). In both cases, values were underestimated, but were able to approximate to oximetry measurements. Crouter developed two equations to be applied according to the characteristics of the evaluated activity. The author distinguished activities on the basis of variability in the activity counts from the Actigraph. In general, a low coefficient of variation (CV) indicates to use the first proposed equation, if variations are high the second model is advised. For this protocol, activities 3 and 4 were better predicted by the first model. Considering that both activities yield more consistent minute-to-minute counts than the other activities (sweeping, moving plastic boxes), which have more erratic movement patterns, the applicability of model 1 was expected.

On the other hand, the best estimations within this group were obtained for activity 6 (Sweeping) by the Swartz wrist-hip equation. This outcome can be explained by the fact that, this specific type of activity (alike the others) was included by the author when developing the equations. And, given the characteristics of the activity, in which upper and lower parts of the body are used, the applicability of the equation with wrist and hip data, is also expected.

Finally, for activities 7, 9 and 10, slightly different results were obtained. As anticipated, Swartz evidenced to provide better estimations. However, contrary to activity 6, in these three cases, the wrist equation proved to be better. For activity 7, predictions were overestimated. Yet, for 9 and 10, energy requirements were underestimated. This last outcome was consistent with the results obtained in the cited study, wherein it was concluded that for those activities in which external work is involved (carrying, lifting, or pushing), equations tended to underpredict the metabolic cost of the activities [20].

Movement with displacement. Special consideration was given for activity 12, as it involves uniform movement patterns and displacement. As a result, besides equations from the last group, equations developed for this kind of activity were also considered. In this regard, two authors [24, 25] proposed equations that were exclusively applicable for walking and running. The equations were tested, but for Freedson's and Crouter's equations, the three positions of accelerometers were verified separately. Results were not strongly conclusive as more than one author gave better results among participants. However, by a simple majority, Swartz equation once again proved to be the most appropriate.

Finally, from the developed experience, a first approach to decision modeling, based on the best results for every activity, is proposed. Figure 2 presents the equations advised for every case and illustrates their associated deviations from measured values. Percentages of error indicate more reliable results than a Level 1

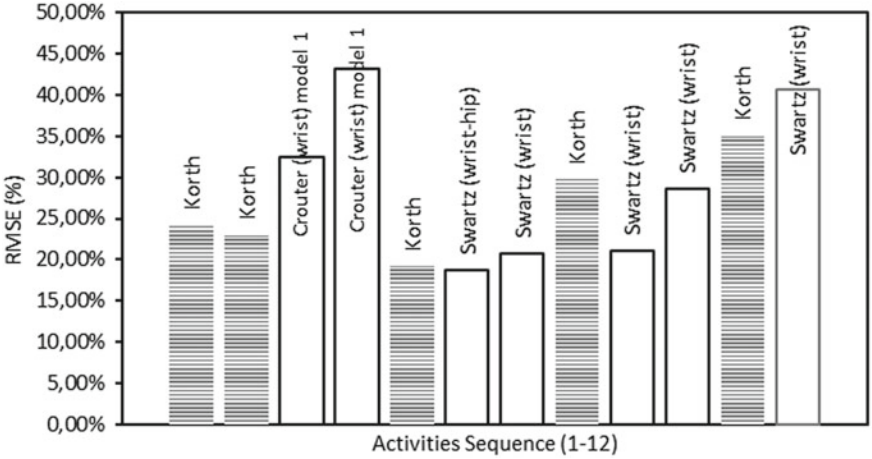

Fig. 2 Decision model for EEE

(and in some cases Level 2) of the assessment approaches referred in the ISO 8996:2004 [3]. In general, the model indicates an average error of 27.46%, which is not distant from the accepted accuracy of Level 2 from the standard, evidencing not only the high applicability of the proposed model, but also the need of its validation within bigger samples.

To conclude, through the developed experience, some inferences could be made. Since the major deviations were obtained in the activities in which movement patterns were measured, it was observed that there are certain limitations to the use of accelerometers for estimating EE. Motion sensors are unable to distinguish between different types of walking surfaces and are not able to detect when a person is carrying a load, pushing an object or ascending stairs [20]. Lastly, for basal energy expenditure, despite the proven applicability of particular equations within the studied sample, it has to be highlighted that the more homogeneous the population, the more accurate the EE prediction, but the less applicable to a heterogeneous group [18]. Therefore, validation of the proposed decision model in other cohorts is needed.

4 Limitations

The number of volunteers must be higher in order to support the reliability of the results and potentially reduce obtained deviations. Furthermore, the addition of more time within each designed activity, would also allow a better comparison of outcomes.

5 Conclusions

With the aim of facilitating the process of energy expenditure estimation, several equations were tested within a laboratory experience. Based on the obtained results, a decision model was proposed. Overall, it is believed that this model, with further validations, can contribute to the process of energy expenditure estimation, permitting its application over a variety of activities and several occupational settings. Future studies should be developed to test the proposed model within bigger samples.

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Good Practices to Reduce Noise Levels in the Neonatal Intensive Care Unit

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Abstract Indoor environmental conditions in neonatal intensive care units, such noise levels above the recommended, may induce some risks, not only for preterm infants' development, but also for health care staff. The aim of this work is to summarize some good practices guidelines that can be followed by health care staff in a daily basis, which are intended to promote noise reduction in neonatal intensive care units. It is expected some initial resistance to the implementation of some recommendations, but evidence shows that in general, with training, health care staff should recognize the need of changes.

Keywords Noise reduction · NICU · Guidelines

1 Introduction

In neonatal intensive care units (NICU), the objective is to keep even the most fragile preterm infant alive until they have developed to a level of medical stability. The NICU is often designed as one large room or "Open-Bay" where staff can monitor multiple infants all in one space. This type of NICU configuration is the

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most common in Portugal. In fact, an open room environment led to unpredictable sounds that contrasts with the protective environment of a mother´s womb [1]. Sound is one of the most pervasive stimuli in the NICU and is perceived differently through the tissues of the womb. For the preterm infant, this is a time when auditory development is taking place and sleep can be affected by constant startles. Noise may also cause physiological stress, which can impact cognitive development and increase length of stay [2]. Several studies performed in NICU, have consistently noted that the recommended noise levels have been violated at day and night periods [3–8]. A recent study conducted in Portugal, shows that noise levels were excessive in all the evaluated areas of the NICUs (noise levels ranging between 48.7 and 71.7 dBA), exceeding international guidelines which proposes that the average background noise in hospitals should not exceed 35 dB LAeq for areas where patients are treated or observed (WHO), 45 dBA daytime/35 dBA night (United States Environmental Protection Agency) and 45 dBA (American Academy of Pediatrics) [3]. The aim for controlling noise levels in the NICU is to preserve a large portion of each hour for infant sleep. Noise levels found in hospitals frequently disturb sleep states and disrupt stable behavioural states in healthy term and preterm infants [9]. Loud sound levels also affect health care staff. Elevated sound levels interfere with adult communication and performance of complex tasks [4]. They also increase fatigue, irritability and work-related stress [10]. Constant exposure, to sound pressure levels greater than 80 dB, will damage health care workers hearing, but those values are not a threat in hospital environment, when comparing with an industrial setting, due to reduced time exposure. In hospital context, safe noise levels are essential for personal communication, family interactions and healthy child development, so it is important for practitioners to understand the current recommendations for the sound levels of these units [11].

2 Purpose

The purpose of this work is to present recommendations for healthcare staff, to reduce noise in NICU, in order to promote an environment that enables the neonate the opportunity to develop and grow to their fullest potential, as well as the health care staff perform their work safely. The recommendations to reduce noise imply the adoption of acceptable noise levels/standards and encouragement and commitment of allied health professionals to work within those levels and decrease extraneous noise. All staff, parents, and visitors must be aware of the effect of noise on premature and ill neonates, to guarantee the achievement of any implemented actions to reduce noise.

3 A Brief Overview of Strategies to Reduce Noise in NICU

Carvalhais et al. [12] in their short review, summarized some studies regarding noise in NICU. They found that neonatal nurses have lack of expertise in noise prevention area, and that they would benefit by becoming involved in an educational program based on prevention of sound stimulation [13]. Indeed, evidence shows that a major strategy to reduce noise is to change the behavior of health professionals [5, 14, 15]. Brown [11] summarizes noise minimization measures to educate the health care team and parents/visitors about the potential consequences of high noise levels and measures for noise reduction, such: reduce conversation at the bedside and move and speak quietly; reduce alarm volumes; respond quickly to telephones, alarms, beeps, crying babies, and other disturbances; avoid putting things on top of incubators; close incubator portholes and drawers quietly; reduce telephone ringer volume; remove radios from the NICU; regularly remove water from ventilator and CPAP tubing; cover incubators with thick blankets or cover to absorb sound; implement a quiet hour protocol; limit the use of the air conditioning system; reduce the volume of beeps or use the vibrating mode; minimize movement of personnel thorough and around NICU; avoid tapping and banging on incubators; avoid leaning on incubators to write; open packaging away from incubators, among others. A well-structured training program also seems to be a low cost measure to start the noise reduction process in the hospital [5]. Staff members can do a lot to change the environment for their patients. For instance, by keeping conversations at a very low level, they discourage loud noises such as laughing, and by being careful not to place equipment (even small items such as pens) on top of incubators. They should be very gentle when opening and closing portholes in the incubators and institute routine quiet periods. Altuncu et al. [16], conducted a study where they measure the noise levels inside the incubator with and without absorbent panel sound (SAP). They prove that SAP reduce noise levels in infant's incubator and is an efficient measure to adopt. Other strategies are noise reduction guidelines, architectural changes, renovation and/or preventive maintenance of equipment, including parameters to the acquisition of equipment containing audible alarms [5]. In fact, several studies have shown that the "private room" or single room NICU environment has been the most effective way to address sound issues, especially when used in conjunction with a cultural change among the staff [17, 18]. Obviously, recently built NICU reap the benefits of improved sound insulation and design. For instance, nowadays, monitor alarms can easily be transmitted visually, eliminating one of the most reported causes for noise production in NICU [3, 19]. Also, shift change discussions should be moved away from the bedside, and devices such as portable x-ray machines should be located as far from the baby as possible. The implementation of a Quit Period or Quiet Hour (QH) in the NICU (reduced light, noise, staff activity and infant handling), has been reported as a good tool with beneficial effects, namely the improvement in some physiological parameters [20, 21]. Many hospital units have their QH in the afternoon, between about 4 and 5 PM, but it varies among units. QH allows healthcare staff to provide these three important elements of good newborn care: More quiet—Providers will try to keep the unit as quiet as possible, and there will be less talking, lower voices, and minimal noise from machines and alarms. Softer light—Lights will be dimmed and shades and curtains will be drawn. Less disruption—Providers will avoid doing procedures and, when possible, fit them in before or after QH. A daily QH reduces newborn stress levels, which helps maintain a healthy blood pressure, heart rate, breathing, oxygen levels, and other important processes [20]. Also, allows for more and better (deeper) sleep, which helps all newborns grow and helps sick babies heal faster. Finally, it will protect preterm infants fragile hearing and promotes healthy brain and sensory development. Despite the obvious role of the health care staff in the implementation of this a QH protocol, the visitors have an important role too. First, they must learn when QH happens. Secondly, they must plan their comings and goings around QH (trying to be in NICU 15 min before QH starts and stay until the hour is over. When fewer people are moving around, the NICU will be calmer during this time). Then, the visitors need to consider the following: spend the hour resting quietly with the newborn, keep conversation to a minimum and turn of the TV and the phone's ringer. However, there are some barriers to the implementation of this protocol, such as: the resistance of health professionals, the limitation of health procedures during this time and the lack of communication regarding the implementation of this protocol to other health professionals from other hospital services.

3.1 Good practices guidelines proposal for health care staff to reduce noise

Some of the following measures were based on Lubbe et al. study [22]. Those guidelines should be included and incorporated in the usual tasks/activities of the staff in NICU, in order to promote a healthier environment for the infants hospitalised. Indeed, some easy measures that can be implemented are:

- Move conversations away the bedside, and use a quiet voice;
- Consider implementing a "QH" on each shift;
- No loud voices/laughing in patient care areas;
- Do not allow incubator doors to snap/click shut;
- Do not tap with fingers, write, or place equipment on top of incubator;
- Cover incubator tops and cribs when indirect lighting is not available to shield individual beds from light;
- Communication devices placed on vibrate mode for patient care areas;
- Wear quiet soled shoes in patient care areas;
- Face alarms away from infants and lower the volume as much as is safe;
- Respond quickly to alarms;
- Minimize respiratory equipment noise by turning off unused baggers and suction and draining water in ventilator circuits;

- Pad storage drawers and doors;
- Use plastic trash cans without lids;
- Conduct “loud” or “noisy” care giving related activities away from the bedside whenever possible; and finally,
- Consider sound control and noise as important factors when purchasing new equipment or making infrastructural modifications at NICU.

4 Conclusions

Collaboration and awareness among all hospital staff and visitors are vital to the success of the proposed recommendations or any new practice introduced. The nursing staff will surely find challenging the accomplishment of the proposed practices. They must modify their work flow to comply with the proposed measures. In general, healthcare staff recognize the problem under noise production in NICU, and this fact will surely help to embrace those guidelines.

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Indoor Air Quality in Hospitals: How Is the Situation in Portugal?

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Abstract Hospitals are complex environments where it is crucial to achieve a good indoor air quality (IAQ) to minimize health risks in patients and workers. The main objectives of this work were to summarise Portuguese legislation regarding IAQ, to review IAQ studies performed in Portuguese hospitals and to compare the results with some European countries, in order to comprehend the suitability of current IAQ laws. Studies regarding IAQ in hospitals were searched in PubMed and through cross-referencing. Legislation regarding IAQ was also researched. IAQ is contemplated in national legislation since 2006. There are few studies regarding IAQ in hospitals, but recent ones reported high levels of particulate matter (PM), formaldehyde, bacteria and fungi. Regarding PM, Portugal reported higher values than European countries. This study reinforced the necessity of evaluating IAQ in clinical settings and establishing guidelines to be applied in complex environments such as hospitals and other clinical settings.

Keywords Indoor air quality · Hospitals · Legislation · Occupational health

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1 Introduction

In the last decades, World Health Organization (WHO) and European Environmental Agency (EEA) have highlighted the importance of maintaining a good indoor air quality (IAQ) [1, 2]. In industrialized countries, people spend 80–90% of their time inside buildings. Indoor contaminants are often present in higher concentrations than outdoor contaminants and are affected by ambient air, building materials and maintenance, ventilation, consumer products and occupants' behaviors [2]. Poor IAQ often results in negative health effects and undermines occupants' comfort and productivity. Since poor IAQ is associated with absenteeism, loss of productivity, concentration and wellbeing of workers, this is a significant societal problem. The European directive nº 2002/91/CE was published to set energy efficiency parameters in buildings [3]. Most European countries followed the directive to accomplish energy requirements and WHO also suggested to set limits for indoor pollutants [1].

Hospitals are a particularly important setting since different groups of occupants may be exposed, and the several performed activities may generate different compounds, that can accumulate indoors [4]. Three groups of occupants can be considered in hospitals: patients, healthcare workers and visitors [5]. These groups have different health status and susceptibilities to chemicals and microbiological agents and are continuously exposed to pollutants such as anesthetics, disinfectants and sterilants.

Poor IAQ and, consequently, exposure to chemicals, particulate matter (PM) and biological agents, is associated with asthma and allergies, lung cancer, and other respiratory and cardiovascular diseases [2, 6]. Total volatile organic compounds (TVOC) are also related with asthma symptoms, and formaldehyde, benzene, chloroform, trichloroethylene and others are considered to be carcinogenic [7]. Biological agents, such as fungi, can induce allergic, infectious, irritant or toxic effects in susceptible persons, and bacteria are also associated with acute inflammatory responses or infections. According to WHO, seven in every hundred hospitalized patients, can suffer from a hospital-acquired (nosocomial) infection [8]. As the infections occur during hospital stay, this leads to its prolongation and an increase in costs and morbidity.

Hospitals are a complex environment that merit special consideration to guarantee a good air quality to protect patients and workers from nosocomial infections and occupational diseases. According to WHO, IAQ is the eighth more important risk factor to human health, being responsible for 1.6 billion of deaths and 3% of disease cases [6]. Thus, it is important to assess IAQ to identify failures and parameters that should be improved. The aim of this study was to summarise Portuguese legislation regarding IAQ and to review related studies performed in Portuguese hospitals to highlight limitations and failures. Additionally, we aim to compare the results with studies in European Union (EU).

2 Methods

The scientific literature used in this review covered studies published from 2000 to 2018 in PubMed and was focused on IAQ in hospitals. The selected search keywords, "indoor air quality" or "IAQ" and "hospital" or "clinical settings", led to 1277 articles, with nine studies being accepted for further analysis. Studies not conducted in hospitals (n = 143), performed in non-EU countries (n = 66), concerning health effects due to pollution (n = 446), regarding IAQ analysis methods (n = 141) and others not related with indoor air quality (n = 472) were excluded. Some studies were found by cross-referencing. Research for legislation in Portugal and in EU was also performed.

3 Results and Discussion

3.1 Portuguese Legislation

In Portugal, IAQ policies are contemplated in national legislation since 2006. The decree-laws nº 78/2006, nº 79/2006 and nº 80/2006, from April 4, approved the National System for the Energy and IAQ Certification of Buildings, the Regulation for the energy and HVAC systems in buildings and the Regulation for the characteristics of thermal behavior of buildings, respectively [9–11]. These regulations appeared with the European directive nº 2002/91/CE concerning energy efficiency of buildings [11]. Most European countries followed the directive to accomplish energy requirements. Indeed, Portugal also defined the minimum conditions for IAQ—included in decree-law nº 79/2006 [10]. This legislation defined maximum concentration levels for some chemical and physical parameters (PM_{10}, CO_2, CO, O_3, CH_2O, TVOC) and microorganisms, and the frequency of audits in public services and institutions.

In 2013, decree-law nº 118/2013, August 20, and missive nº 353-A/2013, December 4, transposed the European directive nº 2010/21/UE and reinforced the promotion of energy performance in buildings [12, 13]. Regarding IAQ, preventive inspections were no longer mandatory and new maximum concentration levels were established [13]. Table 1 presents the limits of chemical, physical and comfort parameters and Table 2 presents the limits of microbiological parameters fixed in the missive nº 353-A/2013. If the measured concentrations are higher than the limits, exact criteria should be followed [13].

The new legislation was questioned by some associations [14]. Although new maximum levels have been established, periodic audits are no longer mandatory, which do not contribute to an adequate safeguarding of public health policy and may not be sufficient to monitor and control incidence of several diseases, such as

Table 1 Protective threshold and tolerance range for indoor air parameters [13]

Parameters	Unit	Protective threshold	Tolerance range
Particulate matter (PM_{10} fraction)	$\mu g/m^3$	50	100
Particulate matter ($PM_{2.5}$ fraction)	$\mu g/m^3$	25	100
Total volatile organic compounds (TVOC)	$\mu g/m^3$	600	100
Carbon monoxide (CO)	mg/m^3	10	–
Formaldehyde (CH_2O)	$\mu g/m^3$	100	–
Carbon dioxide (CO_2)	mg/m^3	2250	30
Radon (Rn)	Bq/m^3	400	–

Table 2 Reference conditions for microbiological parameters [13]

Parameters	Matrix	Unit	Reference conditions
Bacteria	Air	CFU/m^3	Indoor bacteria concentration should be lower than outdoor concentration, plus 350 CFU/m^3
Fungi	Air	CFU/m^3	Indoor fungi concentration should be lower than outdoor concentration
Legionella spp.	Water	CFU/L	Concentration under 100 CFU/L, except in the case of cooling tower tanks where a concentration of less than 1000 CFU/L should be observed. Absence of Legionella pneumophila

Legionnaires' disease. It is important to ensure that some buildings, such as hospitals, follow the established limits, in particular through periodic and compulsory audits.

3.2 *IAQ in Portuguese Hospitals*

There are few studies on IAQ in Portuguese hospitals (Table 3), before and after the publication of the decree-law nº 118/2013. *Araujo* et al. aimed to evaluate the performance of different filters and access conditions upon airborne fungi in hospital facilities [15]. The study evaluated eighteen patient rooms and wards. Air sampling was performed weekly for 16 weeks. The overall mean fungi concentration was 100 CFU/m^3, being in accordance with the legislation published in 2006. In rooms equipped with HEPA (High Efficiency Particulate Arrestance) filtration systems, positive air flow and restrictive access conditions, showed concentrations lower than 5 CFU/m^3. Additionally, in two rooms with no filtration systems, but located inside an ultraclean air enclosure, similar values were observed to the rooms described above. Airborne fungal levels were higher in units where protective clothes were not used, even in those equipped with protective fine filters.

Table 3 Studies regarding IAQ in Portuguese hospitals

Year	Indoor spaces	Parameter	Results	Legislation reference	References
2008	18 rooms and wards	Fungi	99.1 CFU/m^3	500 CFU/m^3	[15]
2009	7 infirmaries from 3 hospitals	CO_2	757–2194 mg/m^3	1800 mg/m^3	[17]
		Fungi	27–960 CFU/m^3	500 CFU/m^3	
2011	31 rooms in a maternity unit	Fungi	9.7% of spaces with >200 CFU/m^3	500 CFU/m^3	[16]
2012	Radiology ward	PM_{10}	13-58.8 μg/m^3	150 μg/m^3	[18]
		$PM_{2.5}$	10.5–41.9 μg/m^3	–	
2014	37 rooms from 2 hospitals	CO_2	1044–1055 ppm	1250 ppm	[19]
		CO	0–5 ppm	9 ppm	
		PM_{10}	20–390 μg/m^3	50 μg/m^3	
		TVOC	0–6 ppm	0.6 mg/m^3	
		CH_2O	0–0.22 ppm	0.08 ppm	
2014	23 rooms	CO_2	<2250 mg/m^3	2250 mg/m^3	[20]
		CO	<10 mg/m^3	10 mg/m^3	
		PM_{10}	10–150 μg/m^3	50 μg/m^3	
		TVOC	0.1–4.5 mg/m^3	0.6 mg/m^3	
		CH_2O	0.05–0.6 mg/m^3	0.1 mg/m^3	
2015	23 rooms	Bacteria	12–736 CFU/m^3	500 CFU/m^3	[21]
		Fungi	1–933 CFU/m^3	450 U/m^3	

Penicillium was the most observed fungal genus, followed by *Aspergillus*. This study reinforced the importance of having rooms equipped with air filters, ante-rooms and medical personnel equipped with protective clothes to control airborne fungi levels. Air and surface fungal contaminations were also evaluated in one Portuguese maternity during a month, in 31 indoor spaces and outdoor [16]. *Penicillium* and *Cladosporium genera* were the most predominant fungi (41.5 and 28.4%, respectively) and *Aspergillus* accounted with 9.1%. The concentration of specific fungi was not described, but 9.7% of the indoor rooms exceed 200 CFU/m^3 in total concentrations. A different study showed normal levels of airborne fungi in six of seven infirmaries of three hospital units located in Porto [17].

Particulate matter was also evaluated in a radiology ward of a Portuguese urban hospital, following the reference values published in the decree-law nº 79/2006, April 4 [18]. PM_{10} ranged from 13 to 58.8 μg/m^3 being the reference value of 150 μg/m^3. $PM_{2.5}$ ranged from 10.5 to 41.9 μg/m^3, but the Portuguese legislation did not consider this fraction. The legislation from 2013 established new reference levels for PM_{10} and included the fraction $PM_{2.5}$, with the maximum values described above being slightly above the protective values but within the tolerance range. $PM_{2.5}$ usually includes metals such as Cr, Mn, Fe, Ni, Zn, As and Pb that have been found in this study [18]. Despite the low abundance in PM fractions, these metals may have adverse health effects, especially Cr, Ni, As and Pb due to their carcinogenic potential.

Since the publication of the new guidelines—decree-law no. 118/2013, of August 20, and missive nº 353-A/2013, of December 4—few studies have been published. In 2014, two hospitals, located in Viseu, were analyzed to evaluate IAQ conditions [19]. The measurements were performed in administrative areas, offices, wards, common rooms, bar, corridors, waiting room and meeting rooms. Hospital A was naturally ventilated with the windows normally closed; Hospital B had air handling units to heat up or cool down the rooms through air ducts. Three out of twelve rooms from hospital A had high levels of CO_2: general office, social service and waiting room. Only three rooms were assessed in hospital B and CO_2 levels were below the reference levels. In the general and social service offices, meeting and activity rooms, TVOC and formaldehyde levels were five times higher than recommended. In Hospital of São Bernardo, Setúbal, chemical and microbiological parameters were assessed in three rooms (emergency service, surgical specialization ward, and surgical room) [20, 21]. In all rooms, the levels of CO, and CO_2 were in line with those published in the legislation. In the emergency service, the levels of PM_{10} and $PM_{2.5}$ were higher than those in legislation, as well as the levels of TVOC, CH_2O and microorganisms. While higher concentrations of bacteria were found during winter, fungi concentrations were elevated throughout the year, but higher values were observed in summer (27–933 CFU/m^3 in summer and 31–132 CFU/m^3 in winter). Regarding ward types, TVOC and CH_2O were higher than the reference values and, in some rooms, the levels of microorganisms were exceeded. In the surgical room, high levels of TVOC were also found, in particular, during the summer. The levels of CH_2O were higher during winter. This work also warned for the need to establish humidity and temperature levels to achieve better control of fungi growth.

In some hospital rooms, lower concentrations of fungi and PM_{10} were observed even before the new legislation of 2013. The current legislation included $PM_{2.5}$ and some limits were re-established. However, IAQ audits were no longer mandatory. Recent studies warned to the exceeded values of some chemical and microbiological parameters in several Portuguese hospital rooms. Additionally, some parameters included in the missive nº 353-A/2013 were not evaluated. For example, when high values of TVOC were observed, no specific measurements were performed. It is important to evaluate IAQ and its effects on the occupants in more hospitals. The legislation should be more specific in these buildings and consider the different exposures between rooms. Humidity and temperature are also important parameters that should be legislated in order to improve the comfort of the occupants and to control the microorganisms' growth.

3.3 IAQ in Europe

Currently, there are no internationally defined IAQ thresholds and monitoring guidelines, and different countries have different limits. However, there are several international entities setting guidelines and standards [22]. These guidelines are intended to provide guidance for reducing the health impacts of indoor air pollution based on scientific evidence. Some of these entities are from the UK, Germany, Finland, Denmark and Belgium. The WHO also contributes to research the health risks of exposure to a poor IAQ and to establish reference safe limits. In the European Union, there are no official guidelines, and WHO guidelines are recommended [22]. In 2011, a study reviewed the IAQ defined in the national legislation of 16 European countries and only six fulfilled this requirement, including Portugal, Finland, Norway, Romania, Lithuania and Slovenia [23]. The study concluded that values in regulations are inconsistent and vary greatly across countries and, in some cases, reference values exceed the ones provided by WHO. In France, a country not included in the previous study, IAQ is defined in national law since 2011 and, in Italy, there are proposes of guidelines to be adopted [24, 25]. Thus, it is important to harmonize recommendations and measurements based on health effects. There are few published studies reporting IAQ in European hospitals.

An extensive analysis to TVOC was performed in a French hospital [7]. Forty-two compounds were identified, and the alcohols were the most found VOC, ranging from 3.1 μg/m^3 for 2-ethyl-1-hexanol to 928 μg/m^3 for ethanol, followed by ether (75.6 μg/m^3) and acetone (22.6 μg/m^3). For all target compounds, concentrations were below the occupational exposure limit values established in France. Concerning to PM, a multicentric study was carried out in 30 hospitals to monitor $PM_{2.5}$ levels [26]. The median values ranged from 1.5 μg/m^3 in Germany to 10.0 μg/m^3 in Romania. In a different study, two French hospitals were evaluated and the similar levels were observed for PM_{10} and $PM_{2.5}$ [27]. The study also reported normal levels of indoor CO_2 (311-841 ppm), bacteria (<1000 CFU/m^3) and fungi (<2500 CFU/m^3), according to French legislation. *Penicillium* and *Aspergillus* were the most observed genera [27], these results were similar to those found in a Portuguese hospital [15]. In Italy, an hospitals reported fungi levels ranged from 34 to 111 CFU/m^3 [28].

There is an extensive work from international institutions and organizations to establish safe health limits for pollutants. Some countries fixed, in national legislations, specific guidelines regarding IAQ despite its non-mandatory nature. However, there are few studies regarding IAQ in hospitals, being difficult to compare results and to evaluate the real status of this issue. Comparing to Portugal, other European hospitals presented lower levels of PM_{10} and $PM_{2.5}$.

4 Conclusions

Hospitals are complex environments due to the activities performed and to the differences of susceptibilities to pollutants from the occupants. In Portugal, the IAQ is contemplated in the national legislation since 2006. But, the need for energy savings by reducing ventilation rates, undervalued IAQ and, since 2013, audits are no longer mandatory. Studies performed after the new legislation reported exceed limits in some parameters, such as, PM, TVOC, CH_2O, bacteria and fungi. Few studies exist in other countries but, regarding PM, Portugal reported higher values than European countries. This study reinforced the need to evaluate IAQ in hospitals and the importance of establishing specific guidelines to be applied in these buildings. Also, humidity and temperature should be defined in legislation to improve comfort and minimize fungal growth.

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Applicability of Heat Stress Index in the Context of Military Work: Pilot Study

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Abstract This study aimed to understand the thermal stress to which young soldiers of the Portuguese Army are exposed in real working context—as in training or activities—in hot climates. The main objective is to verify the applicability of heat stress indexes in this work context. The data used was collected by an experimental method carried out in a partnership between the University of Porto and the Portuguese Army. Two stress protocols were performed in two different environmental conditions: thermoneutral (22 °C and 40 RH) and thermal stress (40 °C and 30% RH). In order to verify the influence of the environmental conditions on the body during military march, with (MWL) and without additional load (WNL), measurements of different physiological parameters were performed, which included monitoring of core temperature, heart rate, oxygen consumption, body mass loss and blood lactate concentration. The WBGT, PHS and UTCI indexes are highlighted in the literature, being for this reason selected for this study. As results, the WBGT underestimated the MWL protocols in thermoneutral environment; PHS has been shown to be limited to higher metabolic rates; and the UTCI proved useful for a first environmental assessment. This reflects in a greater emphasis on the indexes in the environment than in individuals. It was verified that the use of these indexes may not be adequate in the military work, performed in a very hot and dry environment, when it includes march with load and high metabolic rate.

Keywords Thermal stress index · Physiological conditions · Heat stress

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1 Introduction

As a work requirement, military personnel perform missions or activities that include strenuous exercises for long hours and often in hot (or extremely hot) climates [1]. In addition to the effort, they usually need to be equipped with military clothing and heavy equipment, such as backpack, weapon and ammunition, necessary for the survival and success of the missions.

Physiological conditions, drug use, alcohol consumption, among other vulnerabilities play a significant role in the occurrence or not of thermal stress. Therefore, proper management of heat exposure is considered to be responsible for reflecting optimal work capacity and prevention of heat illness/injury [1, 7].

It has been proposed by different researchers a wide range of indexes to evaluate and predict the possibility of thermal stress in the human body when exposed to high temperature environments [10]. Among these indexes, WBGT (wet bulb globe temperature), PHS (predicted heat strain) and UTCI (universal thermal climate index) are highlighted in the literature.

In this sense, this work focuses on the health and safety of military personnel that work in places with high thermal stress, aiming to verify the applicability, in a real working context, of these three thermal stress indexes.

In order to verify the influence of the environmental conditions on the body during exercises, with and without additional load, were studied cases of military personnel under the exposure to dry heat. During the study, measurements of different physiological parameters were performed, which included monitoring of core temperature, heart rate, oxygen consumption, body mass loss and blood lactate concentration.

2 Methods and Data

The materials and data used in this work were obtained from secondary sources, namely a partnership between the University of Porto and the Portuguese Army. The data obtained in this partnership were collected following an experimental method.

This work is consolidated in a documentary research, using materials that did not receive the analytical treatment and that can be re-elaborated according to the objectives of this research [2]. The conditions under which the data were obtained were analyzed to check for possible inconsistencies or contradictions.

2.1 Sample

The sample of this study was young military men belonging to the Portuguese Army, who were selected randomly from the quarters of the country northern region.

The initial sample had 9 individuals and 4 were excluded due to these reasons: 1 physical pain without medical causes; 2 the employment contract with the army ceased during the testing period; 3 for medical reasons and 4 excluded in the scope of this work, due to insufficient data, totalizing an effective sample of 5 individuals.

At baseline, the military were between 19 and 24 years old with a similar physical profile, average weight of 71.1 kg with a standard deviation of 2.8 kg and a average body mass index (BMI) of 23.4 with a standard deviation of 1.

2.2 Test Protocols

The tests were performed in two protocols, each occurring in two distinct environmental conditions: Thermoneutral condition, with the air temperature at 22 ± 0.5 °C with relative humidity of 40 ± 2%; and Thermal stress condition, with air temperature at 40 ± 0.5 °C with relative humidity of 30 ± 2%. This condition was defined to recreate the real conditions of Afghanistan, where the Portuguese Army tends to perform different missions.

For each of these conditions two protocols were performed: Protocol (1) March without load (MNL); and Protocol (2) March with load (MWL).

Both protocols consisted of tests of submaximal intensity, through which it was objectified to achieve the corporal overload prolonging the effort, without changing its intensity during the test. For this, the participants marched on a treadmill, adjusted to 1% inclination, to simulate real soil and wind friction conditions.

The main experimental stage had a maximum duration of 20 min on the treadmill, in which the military marched at 6 km/h. The effort was carried out continuously, without previous heating. All subjects were submitted to this step in the two environmental conditions. It should be noted that the design of the test, which includes exercise duration and treadmill inclination, were developed by the researchers in the original study and the specifications/motivations were not shared.

Both protocols were performed in a similar way, the difference is that in MWL the military was equipped as if on a day of combat training and in addition to the uniform, they were equipped with a backpack prepared for a field day or combat; with belt and chargers; and its weapon, which makes a total of 29.2 kg of additional load.

In order to guarantee the individuals physical integrity, some parameters were controlled prior to the experiments, such as minimal water intake, medication use, sleep deprivation, alcohol or caffeine consumption, and food seasoning.

Medication and drug use may make users more vulnerable to developing heat illness, as well as alcohol may contribute to dehydration and increase body temperature during exercise [8].

In addition, all individuals were considered non-acclimated.

The data collected in the tests were treated with Microsoft Excel 2010 software.

About the calculation of the indexes used in this study, the WBGT was calculated using the software provided on the United States Department of Labor website[1]; the PHS was obtained based on software provided by the University of Lund[2]; and the UTCI was calculated by the online calculator[3] provided by the index authors.

2.3 Stop Criteria

All individuals were monitored in real time, so that, if any of the criteria were extrapolated, the test would be stopped immediately. The core temperature was limited at 38.5 °C since the subjects were healthy and were under continuous medical surveillance with emergency resources readily available [6]; and heart rate, not higher than the maximum heart rate of the individual.

2.4 Equipment and Instruments

In the laboratory tests different equipment and measuring instruments were used, either in the physiological or environmental parameters measurement.

The core temperature was measured intra-abdominal, which approaches the rectal temperature. This measurement was performed using the Vital Sense temperature sensor that were ingested by participants 9–12 h before the experiment start and were not recovered. The measurements were sent through the Equivital EQ02 Life—Sensor Electronics Module, in real time via Bluetooth.

During the tests the heart rate and the lung gases exchange were measured breath-to-breath using the Cosmed K4b2 cardiopulmonary equipment.

Lactate concentration was measured by collecting a blood sample (approximately 0.3 μL) from the participant's right ear lobe before and shortly after exercise completion. Samples were collected at the 3rd, 5th and 7th minutes following the end of the exercise in order to find the peak lactate production. If, throughout these

[1]https://www.osha.gov/dts/osta/otm/otm_iii/otm_iii_4.html (accessed in 09/03/2018).

[2]http://www.eat.lth.se/fileadmin/eat/Termisk_miljoe/PHS/PHS.html (accessed in 09/03/2018).

[3]http://www.utci.org/utcineu/utcineu.php (accessed in 09/03/2018).

collections, the concentration value continued to rise, at 10 min another sample should be collected. These measurements were performed with the Lactate Pro equipment.

Dehydration was calculated by the loss of water mass. In all tests, the participant's weight was collected before and after the tests. After leaving the test the participant showered and changed to ensure that it was perfectly dry at the time of weighing. The weights were collected on a 50 g precision of the brand SECA Model 220.

The tests were carried out in the climatic chamber FITOCLIMA 25000 EC20 in the Occupational Risk Prevention Laboratory (PROA) of the University of Porto.

Inside the camera was installed a treadmill model T2100 of the brand General Electric, which was used to perform physical exercises (with and without load).

3 Results and Discussion

3.1 Core Temperature

In the protocol MNL in thermoneutral condition the maximum temperature reached by the participants had an average of 37.66 °C, with the highest recorded at 38.09 °C, and in thermal stress condition the maximum temperature reached had an average of 37.88 °C, with the highest recorded at 38.02 °C.

On the other hand, in the protocol MWL in thermoneutral condition the maximum temperature reached had an average of 37.95 °C, with the highest recorded at 38.22 °C, and in thermal stress condition the maximum temperature reached had an average of 38.36 °C, with the highest recorded at 38.67 °C. This increase above the limit occurred after stopping the test, in which the temperature continued to rise and then began to reduce until stabilized.

In general, the participant's core temperature (T_{re}) presented higher values when there was with load and in hot environment. T_{re} increased more as a load function, but the hot environment aggravated this condition. In the MWL in thermal stress condition, the T_{re} reached the highest value when compared to all other protocols.

3.2 Heart Rate

The heart rate (HR) increase is also an indicator of the thermal stress experienced. According to the theoretical references studied, the variation of the heart rate is directly linked to the core temperature variation. In general, the participants' HR development was in harmony with the development of the core temperature, according what has been exposed in the literature. In both parameters, the critical values were reached in the MWL protocol in thermal stress condition.

3.3 Oxygen Consumption

There is a direct relation and a proportional variation between the oxygen consumption (VO_2) and heart rate [3]. As discussed in the previous topic, the heart rate of all participants progressed whenever they were exposed to the hot environment, as well as when there was load insertion. Differently than expected, this same variation was not observed in VO_2, which presented higher values mainly in the marches in thermoneutral environment. Verifying the values obtained in the measurement of gas exchange, it was observed that during the execution of the protocols in thermal stress condition the participants' bodies went into anaerobic work.

3.4 Lactate Concentration

Blood lactate concentrations were assessed in order to verify if the load increase during the exercise execution and the thermal stress condition also increase the lactate concentration in the blood. In general, the exposure to hot environment and the inclusion of load reflected an increase in the lactate concentration, presenting the highest concentration in MWL protocol in thermal stress condition.

3.5 Dehydration/Mass Loss

The weight loss was essentially due to the sweating caused by the activity. The mass loss increases in the hot environment with less humidity, and also increases with the load insertion. It was possible to verify that the thermal condition exerted greater influence on the mass loss, showing great impact on the liquids loss.

3.6 Metabolic Rate

The heat exchanges contemplated in the thermal stress indexes used, namely the WBGT and the PHS, are determined based on the standards of ISO 8996.

It was expected that the metabolic rate was higher in the MWL in thermal stress condition. However the highest values were observed in MWL in thermoneutral condition. As discussed in the topic "oxygen consumption", during the exercises in hot environment the participants went into anaerobic work. ISO 8996 allows the metabolic rate calculation as a function of oxygen consumption and not predicting anaerobic work situations [5]. For this reason the values in the MWL in thermal stress may be undervalued. Nevertheless, the metabolic rate calculation was maintained by ISO 8996, since it is the standard predicted in the thermal stress indexes used in this study.

3.7 Thermal Stress Indexes Application

The indexes calculation was performed considering the atmospheric pressure at sea level (760 mmHg) and air velocity of 0.6 m/s. The clothing insolation characterization was supported by ISO 9920:2007. The clothing isolation in the MNL protocols is 0.52 clo and in the MWL 0.64 clo, due to the area of the body isolated by the backpack.

WBGT Evaluation

This method already considers the use of cotton work clothes with I_{cl} = 0.6 clo as reference clothes [4]. The adjustment of the backpack use was not compatible with the clothing adjustment list. Thus, the clothing thermal insulation for the MNL and MWL protocols is treated as being the same.

After releasing the environmental condition data into the software, the returned $WBGT_{eff}$ values were 15.8 °C for the thermoneutral condition and 29.4 °C for the thermal stress condition.

Based on the relation between the reference values and the effective values, the metabolic rate developed by the participants in the MNL and MWL protocols in thermoneutral condition corresponded to a $WBGT_{ref}$ higher than the $WBGT_{eff}$, which points to a scenario that does not pose risks of thermal stress for these individuals.

Under thermal stress condition, for both protocols, the metabolic rate developed by the participants corresponded to a $WBGT_{ref}$ much lower than the $WBGT_{eff}$. Following the indications of the method, this result points to a very alarming scenario, which confers a high thermal stress risk to the individuals exposed to this environment.

PHS Evaluation

There was a limitation, found during the execution of the simulation, regarding the metabolic rate, which was limited in the software to a maximum of 400 W/m^2, while in the MWL protocols the participants achieved values up to 595 W/m^2. With the exception of one participant, all others exceeded the software's metabolic rate limit.

Thus, the simulations for MWL were performed with the maximum metabolic rate of the software—which may have underestimated the core temperature prediction. Due to this, the values returned in these simulations were analyzed with caution.

Overall, in the MNL protocols, the T_{re} predicted by the PHS was more conservative than the real temperature, presenting temperatures slightly higher than those really developed throughout the tests. Around 30–40 min of exercise in a thermal stress condition is foreseen, that all the participants have exceeded the limit of T_{re}.

The T_{re} increase appeared more alarmingly in the MWL protocol, especially in the hot environment, where a fast temperature progression was predicted in a short time.

In general and unlike in the MSC protocol, the T_{re} predicted in the MWL protocol was lower than the temperature really developed during the tests.

It is believed that metabolic rate limitation underestimated the predicted T_{re} (with the exception of the participant who achieved a maximum metabolic rate of 401 W/m^2). If we analyze in isolation this participant, the only one that had the real data simulated in this protocol due to the metabolic rate question, the predicted T_{re} would also be superior to those really developed in the tests.

About the sweat rate, the highest values were observed in hot environment, with values higher than those verified in a thermoneutral environment. This is in line with the test results.

UTCI Evaluation

For the thermoneutral condition, the equivalent UTCI was 21.2 °C, according to the method interpretation it falls into the category of stress: without thermal stress [9]. Therefore, this condition does not represent a source of risk for the thermal stress composition, that is, this environmental condition does not present a potential risk of generating thermal stress in the individuals inserted in this environment.

On the other hand, for the thermal stress condition, the equivalent UTCI was 40.6 °C, it falls into the category of stress—very strong heat stress, which warns of a high risk of exposure of individuals to this environment [9].

4 Conclusions

Regarding the metabolic rate calculation, their determination based on ISO 8996: 2004 was not sufficient for the tests performed in this work. It seems, the majority of the participants entered anaerobic work during the exercises in thermal stress conditions and this type of situation is not foreseen in the standard.

In WBGT index the consideration of "clothing adjustment values" and index correction for a WBGT effective was not sufficient for the suitability of military clothing.

The PHS index was limited to the metabolic rate values reached during the execution of the military march with load in both environments, which reflected in an underestimation of the predicted T_{re}. However, at march without load in both environmental conditions, with the exception of one participant, the model proved to be satisfactory with conservative T_{re} predictions.

The use of the WBGT and PHS indexes as a decisive tool for the evaluation and prediction of thermal stress may not be the most adequate in the context of training and military missions, in very hot and dry environments, which include march and high metabolic rate.

The UTCI model was useful only in the evaluation of the environmental conditions, without considering the effort made by the worker.

The research carried out in this study confirmed that the WBGT is considered as a screening tool in order to identify the existence of thermal stress in a given environment taking into account the metabolic rate. The PHS, though, is indicated to investigate working conditions in the heat, considering the specificities of each individual. Finally the UTCI, as a tool for an initial environmental assessment, is indicative of whether or not to perform some type of activity in the environment under analysis.

5 Limitations and Future Perspectives

As already mentioned, the data used in this study came from a secondary source. However, some of the data from the original study may contain errors that may have propagated for this work.

The determination and understanding of the effects of oxygen consumption on the production of carbon dioxide and its effects on the metabolic rate limited the understanding of this parameter. This relation, his causes and effects must be subject to a more rigorous control and study in future works.

The sample is small, for a more reliable analysis, it is necessary that this study be extended in order to verify the reproducibility or extrapolation of the results obtained and thus guarantee the applicability of these indexes in the conditions outlined for this study.

These indexes are validated only for a restricted metabolic rate. It is suggested for future studies wider researches to validate these models for higher metabolic rates and in more severe environmental conditions than those already consecrated.

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Influence of Permanent Night Work on the Circadian Rhythm of Blood Pressure

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Abstract Night workers exercise their labours activities and rest in contrary schedules to the chronobiological standards. This inversion leads the body to several adaptations, including changes in the circadian rhythm of blood pressure (BP). *Objectives* To evaluate the BP in individuals who perform work at night, in order to objectively detail the BP circadian rhythm adaptations infixed night workers. *Methods* A cross-sectional study enrolling 23 fixed night workers, both genders, was performed, with 24 h BP measured with ambulatory blood pressure monitoring (ABPM) during a normal working day. Risk factors, anthropometric and lifestyle information were collected using a standard questionnaire. *Results* Ambulatory BP demonstrated a pattern of adaptation to the sleep/activity cycle in all participants. BP dropped during the sleeping period (mean drop: -11.35 ± 6.85) and was higher during the awakening period, reaching the highest results and greater BP variability during the working period. The chronobiological adaptation of the 24 h BP was not dependent on sociodemographic or clinical characteristics. In addition, age, male gender, obesity, and those working less time were associated with higher BP mean values. *Conclusions* The circadian rhythm of BP follows the working circadian profile of the individual.

Keywords Permanent night work · Arterial pressure · Circadian rhythm

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1 Introduction

1.1 Night Work and Health Impacts

The night work regime has been linked to a greater predisposition to organic imbalance and disturbances, from which health hazards are more prevailing and projected over the different dimensions of health, including physical wellbeing as well as mental, emotional and social stability [1]. Following a working schedule unmatched with the chronobiological standard, implies sleeping cycles adjusted for periods of biological arousal (daytime), and conversely, activity during periods when the biological systems are more prone to inaction (nighttime), leading to lower physical and cognitive efficiency in working activities. Of course, such behavioral adjustments must be followed by changes in the circadian rhythms of various physiological variables [2, 3], which in turn have been associated with sleep disturbances, gastrointestinal problems, depressive and/or anxious symptoms, and cardiovascular diseases, often related from these workers [4]. In respect to the latter, evidences suggest that the circadian rhythm and the inherent rhythm of working activities are determinants of blood pressure (BP), and thus, shift working and fixed nighttime work provides a suitable environment for the study of the effect of circadian sleep/activity cycles on the twenty-four hour blood pressure profile [5].

Adding to all this internal modifications, additional external factors may add negatively to the adjustment of these individuals to this laboring schedules, such as family harmony, household chores or the noises that end interfering in the sleeping periods. Not to mention the fact that, with this working regime, poor food practices, tobacco consumption, coffee and drugs are also common and contribute negatively to the individual health.

1.2 Circadian Rhythm and Its Physiology

The circadian rhythm (CR), which designates the pattern that organic functions follow during 24 h, is directly related to several environmental variables such as temperature, humidity and luminosity [6]. These vary cyclically, and for the organism survival under the best conditions, it is important that physiological and behavioural processes are expressed in a rhythmic and synchronized manner with environmental cycles [2]. This biological clock is regulated by the suprachiasmatic nucleus, located in the brain [7], which, through the retino-hypothalamic tract, receives information from a photopigment found in the photoreceptors of the retina, the melanopsin [8]. When it receives this information about the external luminosity, this nucleus sends a signal by the upper cervical ganglion to the pineal gland that, in response to the luminosity, prevents the production of melatonin. Already in the presence of a dark environment and with few or any external stimulus, the gland signals the secretion of melatonin [9].

1.3 Melatonin and Cortisol in the Regulation of Sleep and the Circadian Rhythm of BP

Melatonin, among many other functions, acts on sleep induction, insulin production, has antioxidant properties and acts on energy metabolism [10]. Thus, the increase in its production in the absence of light leads to adaptations such as slowing down and decreasing the physiological parameters of the organism (slower cardiac and respiratory rate, decrease alertness and wakefulness, lower body temperature and BP). It increases to a certain plateau during the sleep phase and decreases again with wake-up. Further, during awakening, and opposing to the decrease of the melatonin, there's an increase in cortisol, a corticosteroid hormone, also known as "stress hormone," produced by the adrenal gland and regulated by the circadian rhythm [11, 12]. I opposition to melatonin, cortisol prepares the body for physical and cognitive activity, being associated with marked changes in cardiovascular function and in the metabolism of carbohydrates and proteins [13].

Basal cortisol levels in the blood are higher in the morning, particularly during the awakening period, and slowly and gradually decrease along of day, until they reach their minimum during the evening, signaling the organism that should decrease its activity and thus allowing a collaboration with melatonin [11, 12]. In stressful situations, cortisol activates the body's responses to emergency actions, promoting even greater and acute physiological adaptations. In situations of repetitive and prolonged exposure to stress the hormonal homeostasis may be disrupted leading to an overload of stress hormones, and a state of chronic sympathetic activation [13]. Therefore the chronobiological cycles are related to the balance between melatonin and cortisol, explaining the variation is several physiological parameters suche as BP and heart rate, both decreasing during the sleeping (night and siesta) period and increasing during the activity (day) period [3].

1.4 Effect of Night Work in Melatonin and Cortisol Secretion

Understanding the physiological regulation of melatonin and cortisol in normal circumstances, and its dependence on luminosity, assists in the understanding the existence of important adaptations as a function of the working schedules, particularly whenever night-time labor is considered. It's expected that a night-time worker, being exposed to light and to various external stimuli (light, noise, …) at night and sleeping during the day, will experience hormonal and overall physiological adaptations [14, 15], that are related to the common finding of non-repairing sleep, exhaustion and high BP. In addition to the fact that poor production of melatonin implies changes in the most diverse physiological and psychological aspects, such as the sleep cycle, and that the pattern of cortisol secretion is also altered, some studies have suggested that nocturnal workers have higher BP during the sleep period and are more prone to develop sustained arterial hypertension (AH) [15]. High blood pressure is a major public health problem, with an estimated prevalence above 25% worldwide, which is expected to dramatically increase in the next decade [16]. AH is an important risk factor for cardiac and cerebrovascular events [17], and could contribute to a 40% higher risk of cardiovascular diseases in night workers [18].

1.5 Physiological Adaptation to Night Work

Night work imposes physiological adaptations to the body, which efficacy, size and speed are dependent on several factors, such as the individual's age, sleep habits, type of work, personality, physiological conditions and duration of exposure [19]. The longer the exposure duration, the easier the resynchronization will be. For shift workers, there's a continuous need for physiological adaptation, creating greater physiological unbalances which may impair, not just organic aspects, but also social and cultural dimensions, as the body strives for biological rhythm adjustments whilst maintaining the usual daily activities beyond the working environment. With the inversion of the sleep/wake cycle, a chronological imbalance will occur, but the rhythm of the necessary adaptations isn't uniform, and therefore the challenges to the organism well-being are increased, increasing the risk for maladaptation to nocturnal activity [20]. In certain aspects, the chronobiological cycles do not fully reverse, rather they are slightly attenuated, as is the case of BP, which is only partially inverted [5]. Some individuals never reach a situation of relative balance of their biological cycles and begin to reveal a specific set of nonspecific symptoms that lead to the diagnosis of bad adaptation syndrome in shift work [5]. Further, the challenges of chronological adjustments tend to aggravate with ageing, as a function of lesser physiological flexibility to adapt [5]. Considering the aforesaid, the present study proposes to investigate the adaptations of the BP circadian rhythm in response to night work situations.

2 Methods

Participants were recruited from a logistics company of an international food distribution and s retail group, during the last trimester of 2017. From a total of 100 workers, 23 fixed night shift workers (working schedule: 00–08 h) were enrolled to the study, 3 of them with medicated AH. Initially, all information relating to the purpose of the project and to the methods for data collection were transmitted and informed consent to participate was obtained. Ambulatory blood pressure monitoring (ABPM) was used to characterize the 24 h BP profile. BP was measured non-invasively with an oscillometric monitor, programmed for multiple measurements with 30 min intervals and for a 24 h period. A cuff adjusted for arm diameter was positioned in the non-dominant arm, aligned with the brachial artery. Mean BP and heart rate for daytime, nighttime and the overall 24 h were obtained. AH was defined as the presence of anti-hypertensive medication or mean of 24 h BP > 130/80 mmHg, and/or mean wake BP > 135/85 mmHg and/or mean sleep BP > 120/70 mmHg, following the recommendations of the Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation and Treatment of High Blood Pressure (JNC7) [21].

On the other hand, the evaluation of the sleep BP profile allowed the classification of the dipping status, as an inverted dipper for a rise of BP during sleep, a non-dipper when BP fell between 0 and 10% during sleep, a dipper when it fell between 10 and 20%, and extreme dipper for drops greater than 20% in sleep BP, following the recommendations of the American Heart Association [22]. Body mass index (BMI) was calculated dividing weight by the squared height (weight/height^2) and classified into four classes based on the World Health Organization reference values: a BMI of less than 19 kg/m^2 corresponds to low weight, a BMI of 19.0–24.9 kg/m^2 corresponds to normal weight, a BMI between 25.0 and 29.9 kg/m^2 to overweight and a BMI greater than 30.0 kg/m^2 to obesity. The ABPM was initiated at the beginning of the working schedule, and at the same time point, a questionnaire was filled with demographic and anthropometric information (age, gender, height, weight, BMI), lifestyle information (hours of sleep per day, caffeine consumption and risk factors), work information (activity time in this shift and workload) and other aspects relevant to the study. All the data obtained through the questionnaire and ABPM were compiled in a datasheet.

2.1 Statistical Analysis

The statistical analysis was performed using the IBM SPSS Statistics 24 program. Initially, a simple descriptive statistics of the variables for the total sample and groups (normotensive and hypertensive) were obtained. Quantitative variables were expressed as mean ± standard deviation and compared using the Student t test. The qualitative variables were expressed as absolute count and frequency, and compared using the chi-square and the Fisher's exact tests. The Spearman correlation coefficient was used to address the association of BP and cardiovascular risk factors. The statistical significance was set for a $p < 0.05$.

3 Results

Twenty-three individuals participated in the study, three of them medicated for AH. The remaining 20 referred normal BP, but the ABPM identified 2 participants with new (unknown) AH. The participant's age ranged from 20 to 48 years, with a mean of 30.48 ± 8.31 years. The normotensive group were younger than the hypertensive patients, although the difference in age was not statistically significant

Table 1 Characterization of the sample by age, gender, body mass index (BMI) and body mass index by categories

		Total (n = 23)	Normotensive (n = 18)	Hypertensive (n = 5)	*p*
Age, years (mean ± SD)		30.48 ± 8.31	29.11 ± 7.78	35.40 ± 9.15	0.138
Gender	Male, n (%)	19 (82.6%)	14 (77.8%)	5 (100%)	0.539
	Female, n (%)	4 (17.4%)	4 (22.2%)	0 (0%)	
BMI, kg/m^2 (mean ± SD)		25 ± 3.42	24.48 ± 2.63	26.89 ± 5.41	0.384
BMI categories	Normal weight, n (%)	11 (47.8%)	9 (50%)	2 (40%)	0.017
	Overweight, n (%)	10 (43.5%)	9 (50%)	1 (20%)	
	Obesity, n (%)	2 (8.7%)	0 (0%)	2 (40%)	

Variables expressed in number of individuals (n), and respective percentage (%), and mean ± standard deviation (SD).

Table 2 Presentation of risk factors for all workers and for the study groups (normotensives and hypertensives)

		Total n (%)	Normotensive n (%)	Hypertensive n (%)	*p*
Familiar history of high BP	Yes	10 (43.5%)	7 (38.9%)	3 (60%)	0.400
	No	13 (56.5%)	11 (61.1%)	2 (40%)	
Smoker	Yes	14 (60.9%)	10 (55.6%)	4 (80%)	0.322
	No	8 (39.1%)	1 (44.4%)	1 (20%)	
Cholesterol	Yes	4 (17.4%)	2 (11.1%)	2 (40%)	0.132
	No	19 (82.6%)	16 (89.9%)	3 (60%)	
Diabetes	Yes	1 (4.3%)	1 (5.6%)	0 (0%)	0.590
	No	22 (95.7%)	17 (94.4%)	5 (100%)	

(p = 0.138). Regarding gender, males accounted for 82.6% of the study population, and there were also no statistically significant differences between the two groups (Table 1), despite the fact that all hypertensive individuals were males. In relation to BMI, the mean value found in normotensive individuals was 24.48 ± 2.63 kg/m^2 and in hypertensive patients, 26.89 ± 5.41 kg/m^2, but the difference wasn't statistically significance (Table 1). Relatively to the categorized BMI, for the whole sample, the percentages of workers with normal weight and overweight were similar and only a small percentage suffered from obesity, all of them with AH (p = 0.017). The descriptive analysis of risk factors identified smoking as the more prevailing risk factor, followed by the family history of AH, dyslipidemia and diabetes. Statistical analysis of each factor with the two groups showed no significant differences (Table 2). When questioned regarding the number of sleep hours, 10 (44%) reported sleeping between 4 and 6 h, 12 (52%) between 6 and 8 h and 1 (4%) more than 8 h. No significant differences were observed regarding this variable between groups.

From the analysis of the correlations between all variables, and considering the most relevant variables for the purpose of the study, significant associations were depicted as follows (Table 3): age with nocturnal mean diastolic BP (p = 0.046); gender with mean 24 h, daytime and nighttime systolic BP (p = 0.001; p = 0.001 and p = 0.019, respectively); obesity with mean 24 h, daytime and nighttime

Table 3 Presentation of relevant variables that were found to be statistically significant

		BP systolic 24h	BP systolic diurnal	BP systolic nocturnal	*BP diastolic nocturnal*	*Diagnosis*
Age	ρ	−0.051	−0.007	0.090	0.421	0.272
	sig	0.816	0.974	0.682	0.046	0.209
Gender	ρ	−0.624	−0.624	−0.485	−0.104	−0.242
	sig	0.001	0.001	0.019	0.637	0.266
Obesity	ρ	0.420	0.431	0.442	0.350	0.586
	sig	0.046	0.040	0.035	0.102	0.003
Nocturnal activity time	ρ	− 0.220	− 0.288	− 0.005	0.057	− 0.403
	sig	0.314	0.183	0.983	0.796	0.056

ρ Spearman correlation coefficient

sig Statistical significance ($p < 0.05$)

Table 4 Presentation of the parameters obtained with ABPM for the total sample

Parameters obtained	Mean ± SD	
	Systolic	Diastolic
BP 24 h (mmHg)	122 ± 11.949	72 ± 8679
BP diurnal (mmHg)	127 ± 12.112	76 ± 8845
BP nocturnal (mmHg)	112 ± 11.087	62 ± 8711
Systolic night fall (%)	11.35 ± 6.853	

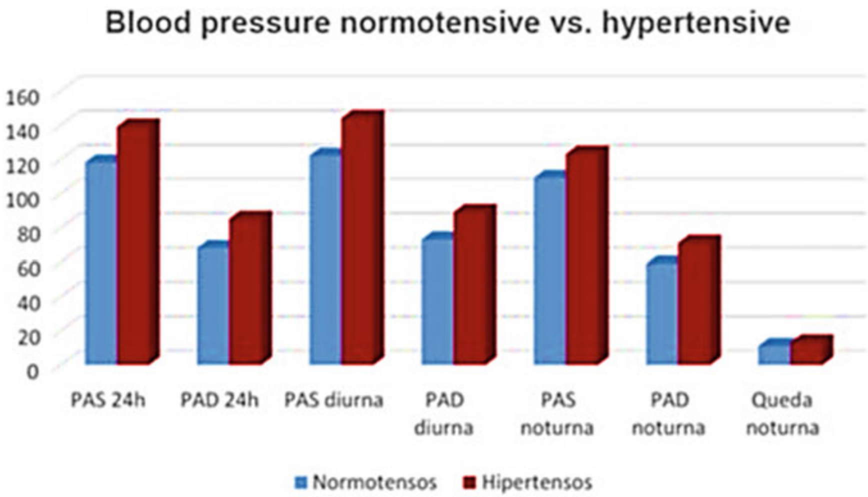

Fig. 1 Representation of averages bloods pressures (24 h, diurnal and nocturnal) in the normotensives group and hypertensives group

systolic BP (p = 0.046; p = 0.040 and p = 0.035, respectively), and with the diagnosis of AH (p = 0.003). As to the historical duration of the nocturnal work, 39.1% referred working in such schedule for 6 months to 1 year, 34.8% for 1 to 6-month, 17.4% for 1–5 year, and 8.7% for less than 1 month.

Considering the mean ABPM values obtained for the all study population, all values are within normal range, including the reduction on sleep BP (Table 4; Fig. 1), notwithstanding the 2 participants with new AH. In addition, only 1 (4.3%) participant was classified as an inverted-dipper. Of the remainder, 6 (26.1%) were classified as non-dippers, 15 (65.2%) as dippers and 1 (4.3%) as extreme dipper.

The comparison between the 2 groups (normotensive and hypertensive) revealed higher mean BP values in the AH group, as expected.

4 Discussion

The evaluation of the 24 h BP profile allowed for the identification of the expected adaptation in the chronobiological rhythm of this hemodynamic parameter, with a fall in BP coinciding with the sleeping period, and higher BP occurring during the activity periods, which is in agreement with previous studies [5]. From the hour BP histograms (not presented) it was also possible to observe that the higher BP and the greater amount of BP variability were registered during the working hours (00–08 h), also as expected. With the approximation of the beginning of the following working period (next day), an increase in BP was also depicted, with the highest BP value coinciding with the first measurement performed at the beginning of the shift, at midnight, possibly translating into the white-coat effect. The hypothesis that age, gender, and risk factors such as smoking, diabetes, and cholesterol, could explain a lower sleep drop in systolic BP, was not confirmed. In addition, it was observed an increase in sleep mean diastolic BP with ageing, which is in accordance with previous studies, notwithstanding the fact that significant relations have been shown also with the other BP variables, and such wasn't observed in the present study although, contrary to the present study [23].

Statistical analysis revealed higher systolic BP in males and in the obese individuals, thus indicating that gender is a major determinant of BP, and also that the overweight and obesity constitute a major contributor do high BP values, in accordance to previous research [24].

Also, it was possible to identify an association of BP with the history of night working, suggesting that the more recent workers are those who have highest BPs, which could translate into a time dependence for the necessary physiological adjustments to occur and to resynchronize the body to the professional context, taking into account that only 4 workers work for over 1 year in night activity.

5 Conclusion

In conclusion, the present study demonstrated that the circadian rhythm of BP is adapted as a consequence of permanent nocturnal work, which indicates a physiological adaptation of the organism to fixed nocturnal exposure, independently of sociodemographic characteristics, risk factors or other external factors included in the analysis. In addition, age, male gender, obesity, and those working less time in night schedules were associated with higher BP.

Future researches
In order to solidly objectify the physiological adaptation that occurs in workers, and even to quantify the inversion observed in this study, we suggest continuing the study in a larger sample, contributing to the increase knowledge of occupational hazards and safety.

Study limitations
As limitations to the study, the ABPM method is known to affect the quality of sleep, so the sleep BP reduction might be underestimated. The small number of participants limited the statistical power of the study, and therefore caution is advised considering the extrapolation of the results.

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The Influence of Health Perception on the Work Ability Index Among Municipal Workers in 2015 and 2017

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Abstract The ability to work is a complex structure affected by a set of different interactions between biological aging, health, skills, organizational context, social context and work activity demands. In the current context of demographic aging, it becomes important to understand how health perception may be related to the reduction of work ability over the years. In order to characterize the work ability, according to health perception, a prospective study was designed. In 2015 the sample included 885 participants and, in 2017, 1167 participants. A self-administered questionnaire was used. The questionnaire was composed of sociodemographic questions, integrating the Work Ability Index (WAI), an adaptation of the Nordic questionnaire for evaluation of musculoskeletal symptoms and the scales of the Portuguese medium version of Copenhagen Psychosocial Questionnaire (COPSOQ II) related to health perception. The results found that the

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mean WAI was lower in 2017, indicating a slight reduction in the ability to work, also WAI correlated negatively with the age. The female workers presented the lowest average WAI. Work ability was influenced by self-reported musculoskeletal symptomatology and the perception of health-related variables. The results indicate that is necessary to implement specific strategies for health promotion, thus contributing to the maintenance of the work ability over the years.

Keywords Work ability · WAI · Health perception · Psychosocial factors · COPSOQ II

1 Introduction

Workability, as defined by the Finish Institute of Occupational Health, is described by the balance between individual resources (physical and mental) and work demands [3, 8]. Several factors seem to contribute to the reduction of work ability over the years. According to different studies, age, professional category, physical and mental demands of the activity, social support, stress and health aspects, constitute some of the main factors [3, 8, 11]. An imbalance between these factors can lead to a reduction of work ability over the years, especially when the work activity seems to undergo recurrent changes, that do not follow the rhythm of biological aging [8, 9].

Changes in the organization and production processes, especially in the technological context, increasing the demand for greater autonomy and qualification of workers, the pace of work, and seldom contemplates the experience, knowledge and skills already acquired by the workers. These factors can trigger mental overload and stress [6]. Increased stress, over the years, may be associated with a decreased ability to work [10]. Concomitantly, aging is associated with a decrease in physical abilities and an increase in musculoskeletal complaints. These changes may reduce an individual's ability to perform their work at the same level of productivity [14].

Therefore, it is justified a study that considers the analysis of work ability, the health perception, and the self-reported musculoskeletal symptoms, seeking to understand how the occupational risks prevention and health promotion can contribute to the maintenance of work ability over the years.

In order to characterize the evolution of work ability among municipal workers from 2015 to 2017, a prospective study was organized in the Portuguese municipality of Sintra. The present paper aims at characterizing the differences on work ability of the workers related to health perception and self—reported musculoskeletal symptoms, comparing the results from 2015 and 2017.

2 Methodology

2.1 Methods

The analysis was done using a questionnaire composed by questions related to the sociodemographic variables, the Portuguese version of Work Ability Index [16], an adaptation of the Nordic questionnaire and the health-related scales of the Portuguese medium version of COPSOQ II [17].

The Work Ability Index is an instrument that evaluates the worker's perception on how well they can perform work based on the perceived interaction of work demands, health, and physical and mental own resources. The results vary from 7 to 49 and are classified as poor, moderate, good or excellent [7, 16].

The Nordic Musculoskeletal Questionnaire (NMQ) was developed with the purpose of standardizing the measurement of musculoskeletal symptoms and, therefore, facilitating the comparison of the results between studies [15]. A general form comprising all anatomical areas was included in the present study. The instrument consists of binary choices regarding the occurrence of symptoms in the last 12 months.

The COPSOQ is an instrument developed by the National Occupational Institute of Denmark, and tested in several studies, in order to standardize and monitor different psychosocial aspects in the workplaces [17]. The health-related scales of the Portuguese medium version of COPSOQ II, regarding General Health, Sleeping problems, Burnout, Stress and Depressive symptoms were used in this study. The scales are scored with a 5 point Likert scale and classified in two cut-off points as critical, intermediate and favorable.

2.2 Population and Sample

The population of this study included 1667 workers of a Portuguese municipality. In 2015 the response rate was of 54.7%, with a total of 885 participants. In 2017, the sample comprised 1167 participants, corresponding to a response rate of 70%.

2.3 Procedures

The questionnaire was self-administered during the years 2015 and 2017. Workers were asked about their interest in participating in the study and those who agreed to volunteer signed the Informed Consent Form. The confidence level assumed for the statistical analysis was 95%.

3 Results

3.1 Sociodemographic Characterization

The sample showed an average age of 46.9 years (sd = 8.3) in 2015 and 48.4 years (sd = 8.7) in 2017. The mean age was higher in the follow up and the differences in the mean values of age between the two moments were statistically significant, according to a T-Student test ($P \leq 0.001$).

In both years there were a higher percentage of female workers and workers under the age of 50 years (Table 1).

3.2 Self-reported Musculoskeletal Symptoms

The self-reported musculoskeletal symptoms in the last 12 months were reported with a higher frequency on Low back (45.2%), Neck (37.9%), Upper-back (33%) and Shoulders (32%) in 2015, and on Low back (49.2%), Neck (40.6%), Shoulders (37.8%) and Upper-back (36.2%) in 2017 (Table 2). The prevalence of self-reported symptoms was higher in 2017 for all the regions.

Table 1 Sociodemographic Characterization

		2015		2017	
		N	%	N	%
Gender	Woman	548	65.6	689	61.8
	Man	287	34.4	425	38.2
Age Groups	<50 years	521	61.2	593	52.8
	> = 50 years	330	38.8	530	47.2

Table 2 Prevalence of self-reported musculoskeletal symptoms

Presence of symptoms in the last 12 months		2015		2017	
		N	%	N	%
Neck	Yes	321	37.9	469	40.6
Upper back	Yes	280	33.0	418	36.2
Low back	Yes	383	45.2	568	49.2
Shoulders	Yes	271	32.0	437	37.8
Elbows	Yes	93	11.0	158	13.7
Wrists and hands	Yes	177	20.9	283	24.5
Hips	Yes	107	12.6	151	13.1
Knees	Yes	194	22.9	276	23.9
Ankles and feet	Yes	144	17.0	198	17.1

When analysed the age distribution among the self-reported symptomatology groups, we found statistically significant differences for the shoulders (2015: $p = 0.004$), hips (2015: $p \leq 0.001$; 2017: $p \leq 0.001$), knees (2015: $p = 0.005$; 2017: $p \leq 0.001$), ankles and feet (2015: $p = 0.003$; 2017: $p \leq 0.001$), regions. The mean age was higher in the groups that reported symptoms.

3.3 COPSOQ II Health Scales

The health scales, whose highest values correspond to the most critical results, that presented the highest averages were General health and Burnout, in both moments of the research (Table 3). The "Burnout" scales ($p = 0.028$), "Stress" ($p \leq 0.001$) and "Depressive Symptoms" ($p = 0.007$) presented significant differences between 2015 and 2017, showing better averages in 2017.

When analysing the health scales according to age and gender, we found that age correlated positively with the scales of General Health perception (2015: r = 0.24; $p \leq 0.001$; 2017: r = 0.25; $p \leq 0.001$) and Sleeping problems (2015: r = 0.11; $p \leq 0.001$), according to the R-Pearson test, indicating that with the increase of the age the results of these scales tends to be worse. We also found that female workers presented statistically significant worse results for all COPSOQ II health scales, in both moments of the research, according to a T-student test ($p \leq 0.001$ for all scales in both years).

3.4 Work Ability Index

In 2015, the WAI showed an average of 40.7 points (SD = 5.1) and in 2017 an average of 40.2 points (SD = 5.1). Both results correspond to a classification of "good" ability to work. The differences in mean WAI values between 2015 and 2017 were statistically significant, according to the T-student test, indicating a slight decrease in the ability to work in two years (Table 4).

Table 3 COPSOQ II health scales Characterization

	2015				2017			
	N	Min-Máx	Mean	S.D.	N	Min-Máx	Mean	S.D.
General Health perception	865	1–5	2.84	0.94	1153	1–5	2.87	0.91
Sleeping problems	865	1–5	2.63	1.06	1153	1–5	2.54	1.07
Burnout	865	1–5	2.83	0.96	1153	1–5	2.74	0.98
Stress	865	1–5	2.72	0.94	1153	1–5	2.58	0.92
Depressive symptoms	865	1–5	2.48	0.96	1153	1–5	2.36	0.94

Table 4 Global score of Work Ability Index

Year	N	Min.	Max.	Mean	S.D.	P
2015	885	14	49	40.7	5.1	0.016
2017	1167	7	49	40.2	5.1	

Age correlated negatively with WAI, in both moments of the research (2015: r = −0.16; $p \leq 0.000$; 2017: r = −0.18; $p \leq 0.000$), meaning that when age increases, the ability to work decreases, according to the R-Pearson test.

When analyzing the distribution of WAI among genders, the female workers presented lower averages in WAI in both moments of the research (2015: $p \leq 0.001$; 2017: $p = 0.023$), and these differences were statistically significant, according to the T-student test.

The Work Ability Index is also influenced by the presence of self-reported musculoskeletal symptoms, with those reporting complaints, showing a lower WAI in both years, for all body regions. The differences between those with and without musculoskeletal symptoms were statistically significant for both years and all body regions, according to the T-student test ($p \leq 0.001$) (Table 5).

Regarding the correlation between the COPSOQ II and the WAI, the scales General Health, Sleeping Problems, Burnout, Stress and Depressive Symptoms, in

Table 5 Work Ability Index characterization by self-reported musculoskeletal symptoms

		WAI 2015			WAI 2017		
		N	Mean	S.D.	N	Mean	S.D.
Neck *	No	523	41.4	4.8	680	41.4	4.7
	Yes	312	39.6	5.5	465	38.4	5.3
Upper-back *	No	561	41.4	4.8	728	41.1	4.8
	Yes	274	39.3	5.4	417	38.5	5.3
Low-back *	No	461	41.9	4.5	582	41.6	4.5
	Yes	374	39.3	5.5	563	38.7	5.3
Shoulders *	No	567	41.4	4.8	712	41.2	4.7
	Yes	268	39.4	5.5	433	38.6	5.4
Elbows *	No	743	41.0	5.0	988	40.5	5.0
	Yes	92	38.6	5.8	157	37.9	5.3
Wirsts and hands *	No	660	41.2	5.1	863	41.0	4.8
	Yes	175	39.2	5.2	282	37.7	5.4
Hips *	No	730	41.2	4.8	994	40.6	4.8
	Yes	105	37.6	6.0	151	37.1	6.2
Knees *	No	645	41.1	4.9	871	40.8	4.7
	Yes	190	39.6	5.6	274	38.0	5.8
Ankles and Feet *	No	695	41.2	5.0	949	40.7	4.9
	Yes	140	38.6	5.3	196	37.6	5.4

Table 6 Correlation between COPSOQ II and WAI

COPSOQ Scales	2015		2017	
	R	P	R	P
General Health perception	−0.59	≤ 0.001	−0.57	≤ 0.001
Sleeping problems	−0.30	≤ 0.001	−0.31	≤ 0.001
Burnout	−0.36	≤ 0.001	−0.38	≤ 0.001
Stress	−0.36	≤ 0.001	−0.33	≤ 0.001
Depressive symptoms	−0.39	≤ 0.001	−0.35	≤ 0.001

which the highest values correspond to the worst results, correlated negatively with WAI in 2015 and 2017, according to the R-Pearson test (Table 6). These mean that when the health-related scales are worse, the results of work ability are lower.

4 Discussion

The WAI has slightly declined from 2015 to 2017, however the WAI average remained in the classification of “Good” ability to work. The average age of our samples was higher in the follow up, what corresponds to the ageing process of the working population and represents a stable population in the municipality, with low level of workers’ turnover. Also, a negative correlation was found between age and the WAI indicating that with advancing age, there is a reduction in the ability to work. Results also found in several national and international studies [3, 4, 8].

The results confirmed that the ability to work is highly influenced by general health perception and musculoskeletal symptomatology, similarly to other studies [12, 14]. The presence of self-reported musculoskeletal symptoms in the last 12 months determined a lower mean WAI. Studies indicate that pain conditions affecting the spine are important sources of reduced work ability, and workers with chronic non-specific musculoskeletal symptoms often have unsatisfactory work ability indexes [2, 18]. The mean age of the workers who referred symptoms was also higher, in the two moments of the research, for the regions of the shoulder, hips, knees, ankle and feet, confirming that advancing age is also associated with increased complaints [14].

In both moments WAI was correlated with the health-related scales of COPSOQ II, meaning that worse health results determine lower ability to work. These results are in line with other studies that showed burnout, stress and depressive symptoms as co-adjuvants in reducing work ability and in compromising workers’ health and safety [1]. Age also correlated with general health perception and sleeping problems, in which older workers presented more critical results on these scales.

In addition, our sample is composed mostly by female workers and was found that female workers presented lower average WAI in both moments and a lower perception of general health. Other studies pointed out that women tend to present higher levels of burnout and stress than men [13].

5 Conclusions

The present study, done in a Portuguese municipality, showed that workers' work ability slightly decreased in a two-year period (2015–2017) and it was influenced by aging, self-reported musculoskeletal symptomatology and the perception of health-related variables. With respect to the gender, female workers were more susceptible of showing lower work ability. The results indicate that is necessary to implement specific strategies for health promotion, prevention of musculoskeletal disorders, managing the stress, burnout and depressive symptoms, thus contributing to the maintenance of the work ability over the years, especially after the changes in Portuguese legislation concerning the extension of the retirement age in the public administration up to the age of 66, thus seeking to concretize measures to address the risks of demographic ageing [5].

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Absenteeism of Public Workers—Short Review

Edison Sampaio and João S. Baptista

Abstract Absenteeism can be defined as an absence of the worker to his work, regardless of the reasons. The objective of this work was to identify the most relevant reasons for public employees absenteeism, through a review of the scientific literature published in the last 5 years. The results pointed out that absenteeism could be associated with several types of indicators. Physical and psychic disorders are very relevant causes, but issues such as organisational justice, stress-reward balance, and demand control, as well as individual employee characteristics and contextual issues, have been strongly correlated with this problem.

Keywords Absenteeism · Public workers · Predictors

1 Introduction

The broad definition of absenteeism includes any absence to work, whether the reasons are legally justified or not [1]. When this absence is due to an illness certified by medical license, it is usually called sickness absenteeism [2]. The non-attendance to work for long-term illness has as consequence that the countries from Organization for Economic Co-operation and Development (OECD) spend about 2% of their gross domestic product (GDP) on disability and sickness benefits. There are several studies on the public workers' absenteeism which represents significant data on its occurrence and impacts [3].

There are, at least, three theoretical models considered more relevant in the literature and, consequently, more used in the study of absenteeism: the sociodemographic model, the medical model, and the working attitudes model. The first

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one includes the employees' characteristics and social contexts. The second model associates the absences to diseases resulting from occupational exposure to different risk factors. Finally, the third model associates absenteeism with issues that generate conflicts between employees and organisations, such as the perception of distributive justice that can compromise organisational motivation and commitment, as well as generate stress and even mental disorders. In this context, the objective of this systematic review was to find and analyse the most relevant studies, developed within the scope of predictors of absenteeism, focusing on the public service.

2 Methodology

This short review was based in PRISMA Statement [4]. From the definition of the objectives, the following databases were screened: Scopus, Web of Science, Academic Search Complete and Science Direct. The searches were performed using the combination of the keywords "absenteeism", "public employees" and "predictors", as well as their synonyms. Regarding the type of document, it was only considered research papers, published between 2013/01/01 and 2018/04/30, in English and Portuguese.

3 Results

3.1 Included Studies

Figure 1 summarises the process of paper inclusion. Initially, there were identified 788 papers. After applying the exclusion criteria, date (except one paper from 2011), type of document (only research articles), and language (papers written in English and Portuguese) there were 204 remaining. Afterwards, 19 duplicate studies were removed, leading to 185 eligible studies. Finally, abstracts were screened and, when necessary, the whole text, in order to verify the work relevance. At this stage, the following screening criteria were considered: sample constituted by public workers, although mixed organizations (public and private employees) were also accepted; studies with the objective of analysing the association between the independent variables and absenteeism; articles with consistent quality level (detailed results, comprehensive discussion, concise and in line with objectives). After applying these criteria, 19 articles were included for detailed analysis.

The selected studies were developed in America, Europe, Asia, and Oceania. That characteristic allowed a broader view of this subject. Table 1 presents all the included papers, informing on authorship, publishing year, country, and objectives.

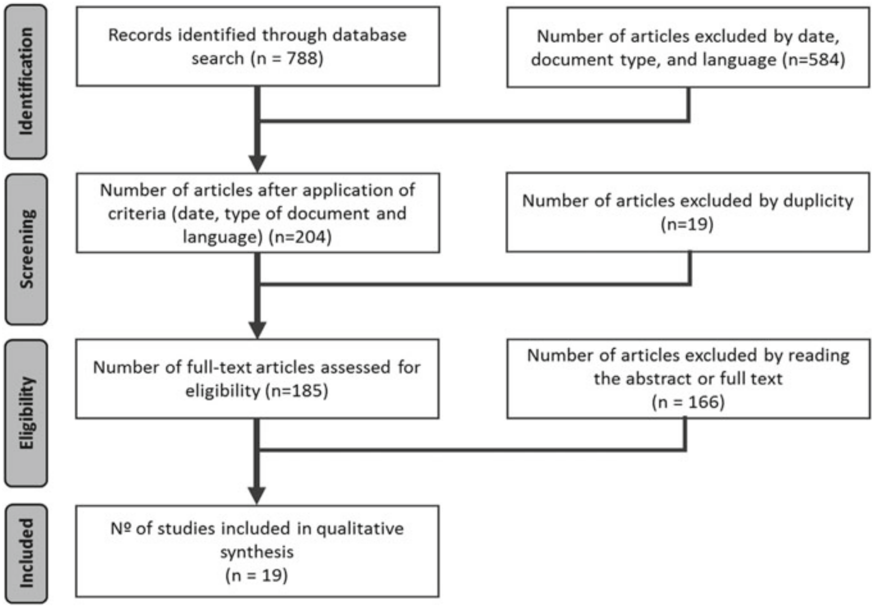

Fig. 1 PRISMA flow diagram [4]

Table 1 Included articles according to the approach

Theoretical model	Study	Year/ country	Objective
Sociodemographics	[5]	2014/NO	To analyse the absenteeism rates (short and long-term)
	[6]	2014/BR	To analyse factors associated with absenteeism-disease
	[2]	2015/BR	To analyse the profile and indicators of absenteeism-illness of municipal employees
	[7]	2017/BR	To describe the epidemiological profile of mental and behavioural disorders (MBD) of public workers
	[8]	2011/IT	To analyse possible determinants of absenteeism in the public sector
	[9]	2014/UK	To investigate whether the behaviour of absence in the past is a predictor of present absenteeism

(continued)

Table 1 (continued)

Theoretical model	Study	Year/ country	Objective
Medical	[10]	DK/2018	To investigate the relationship between bullying and prolonged absences from work
	[11]	CA/2015	To examine the role of professional autonomy, health care setting, and the working environment as risk factors for depression and absenteeism in nurses
	[12]	BR/2017	To analyse the indicators of absenteeism of public workers
	[13]	UK/2017	To analyse the relationship between influenza vaccination and absenteeism
	[14]	USA/2013	To verify the relationship between individual factors and health risks with absenteeism among public employees in the USA
Working attitudes	[15]	FI/2013	To study the association of organisational justice perception with mental health symptoms, as well as to evaluate absenteeism
	[16]	CA/2013	To verify the connection between organisational justice and stress, and absenteeism as an outcome
	[17]	AU/2016	To test the predictive capacity of an expanded model of effort-reward imbalance concerning absenteeism
	[18]	SE/2016	To investigate whether effort-reward imbalance and overcommitment are associated with all causes and mental disorders responsible for long-term medical leave
	[19]	JP/2017	To search the impact of social support and its interrelations with the demand-control model as factors of presentism and absenteeism
	[3]	CA/2014	To investigate how the resources (motivation of self-determined work, and subjective well-being) and the symptoms (psychological suffering) predict the absences due to psychological incapacity
	[20]	USA/2014	To study the relationship between ethical leadership and organisational commitment of public workers, and reduction of absenteeism
	[21]	FI/2017	To examine the association of organisational ethics with absenteeism in a public organisation in Finland

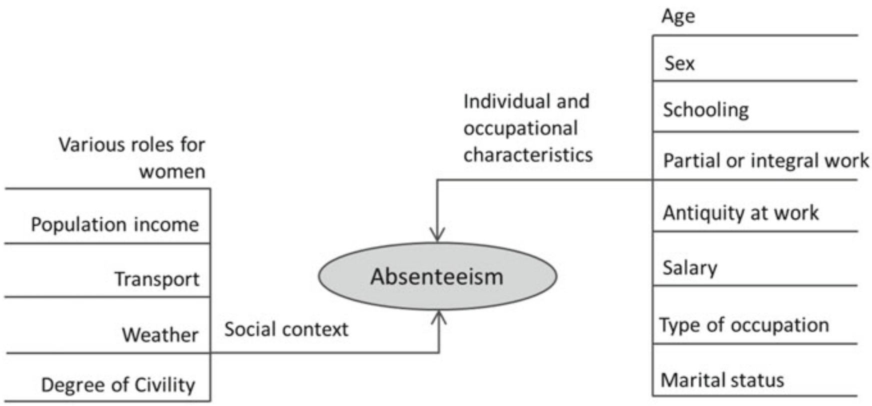

Fig. 2 Sociodemographic approach to absenteeism

3.2 Detailed Results

3.2.1 Sociodemographic Approach

In the studies [2, 5–9], the main variables related to individuals, organisations and absenteeism were: age, sex, working hours (full time or part time), schooling, seniority at work, type of occupation, salary and marital status. On the other hand, other variables related to social contexts such as the degree of civility, employee's mobility conditions (transport), climatic conditions and *per capita* income. Some more organisations characteristic variables were considered in some studies, such as incentives and in-house controls. Figure 2 proposes to represent this type of absenteeism approach.

3.2.2 Medical Approach

Studies related with the medical approach [10–14] present, as main absenteeism predictors, mental and behavioural disorders (MBD), with emphasis on depression, stress, bullying, musculoskeletal diseases, lack of immunisation and comorbidities among employees. These predictors were associated with several variables related to the working environment, to the employee's characteristics, and general working conditions. Due to this approach, absences result from the occurrence of occupational diseases or accidents, which are originated from occupational exposure to different risk factors. Figure 3 is a representation of this model.

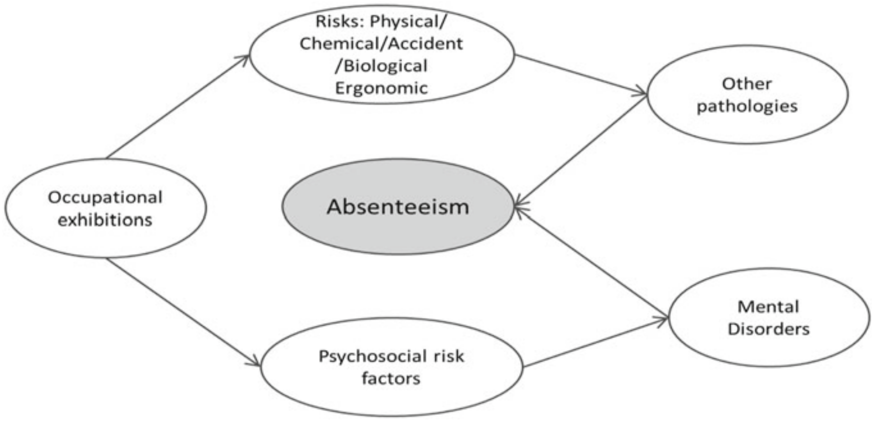

Fig. 3 Medical approach to absenteeism

3.2.3 Working Attitudes Approach

The studies [11, 15–21] present an absenteeism approach from situations referent to relationship conflicts between employees and the organisation where they work. Conflicts are reflected by the negative perceptions from the part of public workers, especially regarding the way of acting, ethical culture and organisational justice that assume the role of risk factors for absenteeism. The primary development of this issue can be the occurrence of stress, demotivation at work, reduction on the organisational commitment and, at the limit, various mental disorders. In this scenario, absences due to mental disorders become a reality in many organisations. Figure 4 represents the relationship between different factors until the final outcome, which is absenteeism.

In Fig. 4 it is possible to determine that risk factors can also act as direct causes for the employees' absence. That would happen, mainly, due to the lack of working motivation, which some authors refer to as voluntary absenteeism, where an

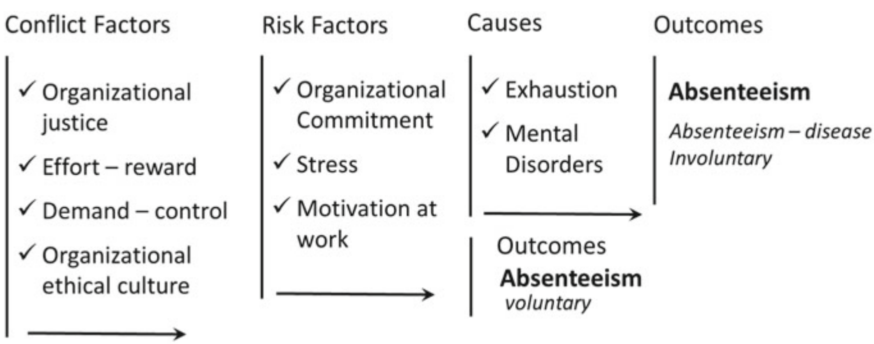

Fig. 4 Working attitudes approach to absenteeism

Table 2 Public workers' absenteeism predictors

Approach	Main predictors
Sociodemographic (*Individual and organisational characteristics*) *social context*	Sex, age, schooling, service time, income, marital status, job, and position, working day Multiple roles of women, *per capita* income, climate conditions, civility degree, family issues
Medical	Mental disorders (i.e. depression, humour, neurotic), bullying, musculoskeletal and connective tissue diseases, comorbidities and other diseases
Working attitudes	Effort-reward imbalance, demand-control relationship, organisational justice, organisational ethics, support at work, affective organisational commitment, motivation at work, stress, burnout, and psychosomatic complaints

Note The predictors can act directly or indirectly since many of them need to establish correlations with each other before the final outcome (absenteeism)

inherent working pathology is not present. Table 2 summarises the absenteeism predictors.

4 Discussion

Regarding the sociodemographic approach, gender, age, schooling and seniority in the position were the main characteristics considered. Women are more absent from work than men, although men lead some absence statistics, as is the case of mental and behavioural disorders, as a result of the use of psychoactive substances [2, 6, 7]. The study [8] revealed the prevalence of female absence, justifying it with the traditional responsibilities concerning home and family. The study [9] found no evidence of female absenteeism prevalence. However, in this case, the organisation had a small number of female servers. It was found that the job absences trend in Norway public workers and Denmark was more significant for the age groups of 20-29 years old and 50–59 years old [5], while the studies [2, 8] have found results that associate absenteeism with older employees. About predictors of absenteeism related to social contexts, the study [8] reported the influence of *per capita* income and civility in northern Italy on the reduction of public employees absences. The studies [6, 8] presented self-report bias, [5, 6, 9] present possible sample bias.

Regarding the medical approach, MBD, especially depression, are more prevalent among absence reasons. This is consistent with the studies [11, 12]. Among the risk factors associated with mental disorders, the reported stress by [14] and bullying reported by [10] were strongly associated with absenteeism. Musculoskeletal system diseases seem to represent the second most significant cause of absenteeism among public workers [2, 12]. Employees' immunisation to prevent some illnesses, especially seasonal ones (especially flu) can have a significant impact on absenteeism, even if it is restricted to these diseases occurrence time. The 10% increase in the vaccination rate of health professionals would have resulted in a reduction of the same percentage in the rate of absenteeism [13].

From the five articles related to the medical approach, in only one was not identified bias. In three [10–12] self-report bias was identified and in one [14] sample bias.

From the identified studies concerning the working attitudes approach, it can be a highlight, mainly, those that associated absenteeism with organisational justice, and the models based on the effort-reward and demand-control imbalance. Such associations were mediated by mental disorders, psychosomatic complaints, work motivation, and affective psychosocial impairment. In this case, the studies of [15–19] can be provided as examples.

On the other hand, the issue of organisational ethics emerges as another risk factor of relevance in the explanation of absenteeism in the scope of the public service. Organisations with low ethical culture can further enhance absences at work, as ethical leadership and consistency of supervisors and senior management influence employees' motivation and commitment, reflecting absenteeism [20, 21]. Working attitudes approach studies presented limitations related to the fact that most of the information is self-reported and, as a result, there are possible information and sampling biases.

5 Conclusion

Overall, the studies result allowed a broad overview of the absenteeism determinants, within official bodies, in various economic and cultural realities. Due to the nature of the results, it was well established that absenteeism is a multi-causal phenomenon and may be associated with determinants of the most varied reasons. The list of possible predictors of absenteeism proposed by the authors provides a good measure of this diversity. Absences of public workers from work are associated with the different pathologies, but may also be a direct reflection of the lack of motivation or even the lack of commitment related to the factors of conflict with the organisation.

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Is the Quantitative Cut-off a Suitable Surrogate to Ensure a Good Indoor Air Quality Regarding the Mycobiota in Health Care Facilities?

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Abstract Control measures are crucial in clinical environments for reducing concentrations of airborne fungal and, consequently, to avoid invasive infections acquired from indoor air. This study intends to assess mycobiota in 10 Primary Health Care Centers (PHCC) applying the Indoor Air Quality Portuguese legislation as guidance. After the quantitative cut-off analyses (ratio between indoor and outdoor load (I/O)) the fungal species identification was performed to verify if the fungal conformity was achieved. Fungal assessment was realized by air samples through an impaction device and consisted mainly of one indoor sample in each sampling location and one outdoor sample, to be used as a reference. Among the 10 PHCC 60% (6 out of 10) presented I/O > 1. However, in two PHCC that comply with the quantitative cut-off toxigenic species were identified. The quantitative cut-off applied to assess IAQ is not a suitable surrogate to ensure a good air quality and qualitative assessment should always be performed to guarantee an accurate assessment.

Keywords First keyword · Second keyword · Third keyword

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1 Background

Studies have reported that there is a significant relationship between hospital infections and bioaerosols [1]. Fungi are present in clinical indoor environments and play important roles in human diseases in patients and staff. The infections among patients are increasing in immunosuppressed patients [2] and *Aspergillus* is a common fungus in invasive infections, however, other fungi are enrolled as pathogens in immunosuppressed patients [3]. Additionally, the azole-resistant *Aspergillus* sp. has up to 30% prevalence in some European hospitals, which report higher than 90% mortality rates [4].

Control measures are crucial in clinical environments for reducing concentrations of airborne fungal contamination and, consequently, to avoid invasive infections acquired from indoor air [5, 6]. Furthermore, we cannot fully eliminate fungi from indoor clinical environments [7] and enforcement is needed to ensure, at least, proper Indoor Air Quality (IAQ) assessments.

Portuguese legislation established limit values for air bioburden in indoor environments in general, without any specific requirement for health care facilities [8]. Concerning mycobiota indoor load should be less than outdoor [8]. However, when this condition is not satisfied, there is a second opportunity to meet the legal requirements according to Tables 1 and 2 [9].

This study focuses on the mycobiota assessment in 10 Primary Health Care Centers (PHCC) applying the IAQ Portuguese legislation as guidance. After the quantitative cut-off analyses (ratio between indoor and outdoor load (I/O)) the fungal species identification was performed to verify if the fungal conformity was achieved even in those that comply with the I/O ratio.

2 Materials and Methods

This assessment belonged to an enlarged exploratory study aimed at establishing protocols to assess occupational exposure to bioburden in clinical environments. The study was conducted between June and September 2018 in 10 Portuguese Primary Health Care Centers (PHCC) located in the Lisbon district, but it will also

Table 1 Portuguese legal compliance for mycobiota according to Ordinance no. 359-A/2013

	Fungi
1st requirement	• [indoor] < [outdoor]
2nd requirement (to be applied when the 1st requirement is not fulfilled)	• No visible fungal growth on surfaces; • Species should be evaluated according Table 2

Adopted from [10]

Table 2 Fungal conformity based on the species according to Ordinance no. 359-A/2013

Genera/Species		Specific Condition of Conformity
Common species	*Cladosporium* sp. *Penicillium* sp. *Aspergillus sp.* *Alternaria* sp. *Eurotium spp* *Paecilomyces* sp. *Wallemia* sp.	Mixture of species: ≤ 500 CFU.m^{-3}
Non-common species	*Acremonium* sp. *Chrysonilia* sp. *Tricothecium* sp. *Curvularia* sp. *Nigrospora* sp.	One species: < 50 CFU.m^{-3} Mixture of species: < 150 CFU.m^{-3}
Pathogenic species	*Chryptococcus neoformans* *Histoplasma capsulatum* *Blastomyces dermatitidis* *Coccidioides immitis*	Absence of any species
Toxigenic species	*Stachybotrys chartarum* *Aspergillus versicolor* *Aspergillus flavus* *Aspergillus ochraceus* *Aspergillus terreus* *Aspergillus fumigatus* *Fusarium moniliforme* *Fusarium culmorum* *Trichoderma viride*	One species: < 12 CFU.m^{-3} *(Several colonies per plate)*

Adopted from [10]

comprise a Portuguese Central Hospital. The results presented will focuses only on mycobiota, considering the Portuguese legal enforcement as guidance to perform the assessment.

Fungal assessment was achieved by air samples through an impaction device and consisted mainly of one indoor sample in each sampling location (between 8 and 11) and in one outdoor sample in each PHCC, to be used as a reference. The sampling locations were 8 for most of the PHCC (7 of 10): Medical Office; Waiting Room; Treatments Room; Vaccination Room; Front Office; Back Office; Cleaning Supplies Room and Canteen. In one of the PHCC (Number 7) 3 additional sampling sites were assessed, namely: Oral hygiene office and Sterilization Area—Clean and Unclean.

Air samples of 250 L were collected with a flow rate of 140 L/min (Millipore air Tester, Millipore, Billerica, MA, USA) onto each plate of malt extract agar

(MEA) supplemented with chloramphenicol (0.05%) according to manufacturer's instructions. The air sampling plan followed the guidelines of the national legislation [9].

All air samples were incubated at 27 °C for 5–7 days (fungi). Fungal densities (colony forming units (CFU) per m3) were calculated, followed by fungal identification achieved through macro and microscopic characteristics, as noted by De Hoog et al. [11].

3 Results

The median values on MEA ranged from 164 CFU.m^{-3} (in the clean area of the sterilization room) to 508 CFU.m^{-3} (in the treatments room). Among the 10 PHCC 60% (6 out of 10) presented I/O > 1 (Table 3).

Among the toxigenic species covered by Portuguese legislation *Aspergillus versicolor* (*Aspergillus* section *versicolores*), *Aspergillus ochraceus* (*Aspergillus* section *Circumdati*) and *Aspergillus fumigatus* (*Aspergillus* section *Fumigati*) were identified in the air from the PHCC analyzed. The load of *Aspergillus* section *Versicolores* surpassed 12 CFU.m^{-3} in PHCC 2, 3 and 6. Regarding *Aspergillus* section *Circumdati* the load was surpassed in PHCC 2 and for *Aspergillus* section *Fumigati* in PHCC 5.

Besides the aforementioned *Aspergillus* sections, the sections *Nigri*, *Aspergilli* and *Nidulantes* were also observed.

Table 3 Fungal air load mean, outdoor and I/O values

PHCC	Mean (CFU.m^{-3})	Outdoor (CFU.m^{-3})	I/O	Toxigenic species*
1	28.57	144	0.20	
2	65	20	**3.25**	*Aspergillus* sections *Circumdati* and *Versicolores*
3	479	612	0.78	*Aspergillus* section *Versicolores*
4	402	260	**1.55**	
5	291	96	**3.03**	*Aspergillus* section *Fumigati*
6	155.5	228	0.68	*Aspergillus* section *Versicolores*
7	474.91	140	**3.39**	
8	526	384	**1.37**	
9	505.71	508	1.00	
10	520	208	**2.50**	

* Not complying with specific condition of conformity

4 Discussion

Clinical environment, as the PHCC analyzed, requires special attention to guarantee healthy indoor air quality (IAQ) to protect patients and healthcare staff from hospital-acquired (nosocomial) infections and occupational diseases [12]. As such, mycobiota assessment should be ensured not only to comply with Portuguese legislation, but also because fungal infections predominantly occur in immunocompromised patients and many are acquired in hospitals [13]. Additionally, *Aspergillus* genus should always be target in clinical environment and should be considered as a main IAQ concern. Besides, invasive aspergillosis (IA) due to *Aspergillus* section *Fumigati* accounts for 80% of the total of invasive fungal infections, and because of that *Aspergillus* sp. should always be assessed and preventive measures implemented [14]. Indeed, four *Aspergillus* sections (*Flavi*, *Fumigati*, *Circumdati* and *Versicolores*) are considered as indicators of harmful fungal contamination indoors [15].

Data from this study allowed to concluded that even if the I/O ratio cut-off is in accordance with legislation [8] we should always proceed and perform qualitative assessment from the fungal burden (fungal species/sections identification), since toxigenic species can be present, as happened on PHCC 3 and 4 even though the cut-off complied with legal requirement. In addition, assessment should not be restrictive to the fungal species mentioned in Portuguese legislation, since not all fungal/species with toxigenic potential, and common in indoor environments from Portugal, are listed (as the ones belonging to *Aspergillus* genus and also identified sections *Nigri*, *Aspergilli* and *Nidulantes*).

Other critical aspect is the fact that Portuguese legislation only relies on active methods (air sampling) and this can narrow the exposure assessment, since production and fungal spore release varies significantly from species to species, influencing its dissemination in the air/surfaces [16]. However, in most of the studies where fungal assessment was reported, the results have been achieved only by air sampling [17]. Of note, are the limitations of using air sampling as standalone method, since this method only reflect the load from a shorter period (mostly minutes) [18], whereas all passive methods (such as swabs and electrostatic dust cloths) can collect contamination from a larger period of time (weeks to several months) [19].

Molecular tools should also be used, although viable fungi, assessed by culture based-methods are the ones posing higher health risks when compared with non-viable organisms [20, 21]. Targeting harmful fungal species, like the ones listed in Portuguese legislation and other with clinical relevance and/or toxigenic potential, will allow an enriched IAQ assessment [18].

5 Conclusions

In light of the results, the quantitative cut-off applied to assess IAQ is not a suitable surrogate to ensure a IAQ regarding the mycobiota in health care facilities. Qualitative assessment, besides the quantitative, should always be performed to guarantee an accurate assessment, even though the quantitative cut-off comply with the legal requirement. A multi-approach on sampling methods and in assays (culture based and molecular methods) will enrich data findings, enabling industrial hygienists and public health officers to perform IAQ assessments.

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Influence of Severe Cold Thermal Environment on Thermal Sensation and Physiological Responses

Tomi Zlatar, J. Oliveira, J. Cardoso, D. Bustos, J. C. Guedes and João S. Baptista

Abstract Exposure to cold affects health and poses significant risks for cardiovascular diseases, musculoskeletal complaints and symptoms. It is present in outdoor activities in high latitude environments and within different occupations, causing variations in core and skin body temperatures and affecting working performance, health and safety. This work aims to evaluate the changes in thermal sensation, and in some physiological parameters before, during and after exposure to the severe cold thermal environment (SCE) (−20 °C) of subjects wearing cold protective equipment. By using the Thermal Sensation Questionnaire (TSQ), blood pressure equipment, thermometer telemetry capsules and 8 skin temperature sensors, a study was conducted on 11 non-acclimatized male volunteers with a 60-minute exposure. The results show variations in all measured parameters. Findings evidence decreases in located skin temperatures and recovery periods for each measured point and increases in core temperature despite exposure to SCE. Future studies should be conducted using more skin temperature measuring points in the extremities (face, fingers and toes).

Keywords Cold exposure · Thermoregulation · Physiological response

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1 Introduction

Exposure to the cold thermal environment is a significant risk factor in industrial activities, present in outdoor during the winter season and indoor in all seasons [1]. Indoor exposure is mostly related to working activities in the fresh food industry, with temperatures from 0 to 10 °C, and frozen goods at temperatures below −20 °C. Cold exposure in outdoor activities is present in activities such as fishery, army, agriculture, forestry, mining, factory work, construction work and related occupations [2].

Outdoor exposure to cold is of particular interest in high latitude regions where winter last for several months [3]. The reaction to cold is dependent on several factors such as occupation, gender, age, health and exercise activity [3]. Exposure to the cold thermal environment increases muscular strain and musculoskeletal symptoms [4]. The cooling of the tissues leads to discomfort, performance deterioration and work accidents increase [5].

It is necessary to increase the quantity and quality of studies dealing on the effects of exposure to severe cold thermal environment (SCE) on working performance since there is still a significant lack of knowledge about its real effects [6]. Thus, this study aimed to evaluate the influence of exposure to the SCE of both, subjective and physiological responses of subjects wearing cold protective equipment.

2 Methods

Experiments were performed at the Laboratory on Prevention of Occupational and Environmental Risks (PROA) of the Faculty of Engineering of the University of Porto and approved by the Ethics Committee of this university (06/CEUP/2015). The volunteers were fully informed about the experimental procedures and were briefed on purpose, potential risks and benefits of the experiences. Additionally, written consent was read and signed by them before starting the trials. The trial duration was 3 h: 30 min before exposure to SCE for sitting activity, 60 min of exposure to SCE for protocol activities, and 90 min after exposure to SCE for sitting activity (Table 1).

Eleven non-acclimatized male volunteers aged 23.909 ± 3.360 (years ± SD) and weighted 77.036 ± 7.785 (kg ± SD) participated (Table 2).

The experiments were conducted inside a climatic chamber (Fitoclima 25000EC20). Outside the chamber, temperature and relative humidity of the laboratory were measured with a calibrated thermohygrometer (HANNA D0108069).

Skin temperature (T_{skin}) was measured with Bioplux skin temperature sensors on the 8 measuring points indicated by the ISO 9886:2004: forehead, right arm in upper location, right scapula, left upper chest, left arm in lower location, left hand, right anterior thigh and left calf [7]. Core temperature (T_{core}) was measured through

Table 1 Experimental stages and recorded variables

Trial stage	Before SCE (±18 °C)	Exposure to SCE (± −20 °C)			After SCE (±18 °C)
Duration (min)	30	Phase 1: 20	Phase 2: 20	Phase 3: 20	90
Activity	Seated	Exercise			Seated
TSQ (min)	10′	0′–20′–40′–60′			5′–20′–40′–60′–90′
HR–BP (min)	10′	No measurements			5′
T_{core} and T_{skin}	Continuous				

Table 2 Subjects characteristics

	Age (years)	Height (cm)	Weight (kg)	BMI (kg/m^2)
Mean	23.909	178.555	77.036	24.170
SD	3.360	5.122	7.785	2.046
Min	21.000	166.000	62.900	21.260
Max	33.000	185.000	89.500	27.470

intra-abdominal Equivital Ingestible Pill Sensor. It was swallowed with water at least 5 h before each test. The sensors send records every 15 s to the EQ02 Life Monitor—Electronics Sensor Module (SEM) via Bluetooth.

The systolic (SBP) and diastolic (DBP) blood pressure and heart rate (HR) were measured with OMRON M10-IT Intellisense Upper Arm Blood Pressure Monitor. They were recorded on the left arm for three consecutive times with a 15-second interval between measurements. The mean value of SBP, DBP and HR were registered 2 times each: 10 min before exposure to SCE and 5 min after exposure to SCE, outside the climatic chamber.

General lifestyle questionnaire (GLQ). A general questionnaire was elaborated in order to get some primary data on the volunteer's characteristics and lifestyle. The questions included: the date of birth; profession; smoking and drinking habits, ingestion of coffee, tea or spicy food in the past 12 h; hours past from last meal; last meal; medications currently taking; times of sleeping and waking up, as well as the number of sleeping hours; if he was right/left-handed; frequency (per week) of sports practice.

Thermal sensation questionnaire (TSQ). The TSQ, based on the Annex B of the ISO 10551:1993 [8] was answered 10 times during each trial: 10 min before exposure to SCE; right after entering; after 20, 40 and 60 min of SCE; and 5, 20, 40, 60 and 90 min after exposure to SCE. Additionally to the ISO TSQ, questions 6, 7 and 8 were added to get feedback on the located sensation of the volunteer.

Clothing. The volunteers wore special cold protective equipment: jacket with a hood (2.23 clo), trousers (2.07 clo), boots (0.1 clo) and gloves (0.05 clo) above their normal clothing: socks (0.02 clo), underpants (0.03 clo), undershirt (0.09 clo), trousers (0.25 clo), and thinly long-sleeved shirt (0.28 clo). Taking as a reference the ISO 9920:2007 [9], the total insulation value was about 5.12 clo during exposure to SCE.

Initial meeting. One week before the experiment, the research team met the volunteers for the first time, to explain the purposes and characteristics of the study and possible risks of their participation, get their general and lifestyle information and schedule their medical control.

Medical examinations. They were done in Hospital São João, Porto, Portugal, in order to select healthy volunteers and assure their aptness to take part in the experiment. Each volunteer was examined to check for cardiac and vascular diseases, respiratory impairments, gastrointestinal diseases, and intolerance to cold, cold urticaria conditions, other forms of urticaria or angioedema, musculoskeletal alterations, allergies, illness history and any prescript medications. After that, the informed consent was read and signed and the experimental days were scheduled. One day before the experience, the research team met the volunteers again in order to ask for health-related changes that might have occurred in the meantime. The T_{core} pill was given and an explanation on how and when to ingest it was provided.

Before entering the climatic chamber. In the climatic chamber, there were four main points: (A) the table on which each session started and ended, with: three standard A4 paper boxes (each weighting 5 kg), one box with 12 crumpled papers, and two pairs of plastic bottles with glass balls inside them (each pair weighting 0.8 kg); (B) a cabinet with three shelves on different levels (shelf 1—10 cm, shelf 3—80 and shelf 5—150 cm from the ground); (C) a cabinet with two shelves on different levels (shelf 2—45 and shelf 4—115 cm); and (D) part of the chamber with two papers taped on the wall: one with the experimental protocol to remind the volunteers about the tasks sequence, and the TSQ. The trials were aborted if one of the following conditions were registered:

- the volunteer felt any symptoms such as dizziness, nausea and general malaise;
- the T_{core} got lower than 36.0 °C (lower limit value from the ISO 9886 2004);
- the local T_{skin} (in particular on the extremities: face, fingers and toes) got to 15 °C (lower limit value from the ISO 9886 2004).

In order to minimize potential biases related to the influence of the circadian rhythm on the results, it was conducted one trial per day, always at the same time [10] and with the laboratory at the same temperature (18.0 °C). The volunteers were met at 09:15, and the core body temperature pill was checked in order to assure its functioning. Height and weight were measured wearing just the underpants. After placing the sensors, they dressed the Equivital chest belt. Subsequently, they dressed back up with socks, long sleeved trousers, a t-shirt and long-sleeved shirt and all wires were put in one small handbag to facilitate displacement. The equipment was turned on, and the recording started from 30 min before they entered the climatic chamber. Later, they sat down, completed the GLQ and the experimental protocol was explained. Ten minutes before entering the climatic

Table 3 Experimental protocol during exposure to SCE

Sequence	Activity	Duration
1	Thermal sensation questionnaire	4 min
2	Walk and heat the hands (1 min)	
3	Put four papers in each box (one by one)	
4	Close the boxes	
5	Put the boxes one by one to position 1	
6	Rest 1 min (heat the hands)	
7	Put the boxes from position 1 to position 2 (one by one)	4 min
	• Rest 5 s (heat the hands)	
8	Put the boxes from position 2 to position 3 (one by one)	
	• Rest 5 s (heat the hands)	
9	Put the boxes from position 3 to position 4 (one by one)	
	• Rest 5 s (heat the hands)	
10	Put the boxes from position 4 to position 5 (one by one)	
11	Rest 1 min (heat the hands)	5 min
12	Do the game with glass balls 10×	
13	Rest 1 min (heat the hands)	
14	Put the boxes from position 5 to position 4 (one by one)	4 min
	• Rest 5 s (heat the hands)	
15	Put the boxes from position 4 to position 3 (one by one)	
	• Rest 5 s (heat the hands)	
16	Put the boxes from position 3 to position 2 (one by one)	
	• Rest 5 s (heat the hands)	
17	Put the boxes from position 2 to position 1 (one by one)	
18	Rest 1 min (heat the hands)	3 min
19	Put the boxes one by one to the table	
20	Open the boxes	
21	Put four papers from each box to the starting point (one by one)	
22	Walk and heat the hands (1 min)	

chamber, their BP, HR and TSQ answers were also registered. Five minutes before entering, they put on the previously described cold protective clothes, leaving exposed the part of their eyes, cheeks and nose. Finally, the volunteers entered the climatic chamber.

Inside the climatic chamber. During the exposure to SCE, the experimental protocol of 20 min (Table 3) was repeated 3 times. Protocol times were controlled through a chronometer, and when necessary, the researcher indicated to accelerate or slow down the activities to assure the designed duration and a similar cadence among participants.

After exposure to SCE. When the volunteer exit the climatic chamber, he firstly undressed the cold protective gloves, jacket and boots. Afterwards, he sat on a chair throughout the recovery period and BP, HR and TSQ answers were re-recorded. The volunteer was not allowed to drink anything, go to the toilet or walk around until the trial finished. After 90 min of recovery period, the T_{skin} and T_{core} recordings were stopped, the equipment was removed and his body weight was measured again.

T_{core} was recorded by using the Equivital Manager and EqView professional programs. When the T_{core} values were of −1 °C, they were considered as outliers and excluded for later analysis and graphics. T_{skin} was recorded by using the MonitorPlux program. The mean skin temperature was calculated using the weighting coefficients suggested by ISO 9886:2004 [7]. Obtained data were processed by an algorithm developed using Pandas, a Python 3.6 library for data analysis and statistics.

3 Results and Discussion

The present study examined the responses of intra-abdominal T_{core}, T_{skin}, HR and blood pressure (DBP and SBP) during a 3-hour experience that included a protocol with exposure to SCE (−20 °C). In general, all measured parameters presented alterations when submitted to the characteristics of the designed protocol. However, the most remarkable outcome was the fact that, despite the anticipated variations in physiological responses, obtained results did not exceed reference limit values [7].

Recorded values were processed, and individual responses were analyzed considering the evolution along the time (Fig. 1). Dashed lines denote the three 20-min phases of exposure to SCE. Left hand and Forehead temperatures were also included, since they were the ones evidencing more variations and greater influence in the mean T_{skin}.

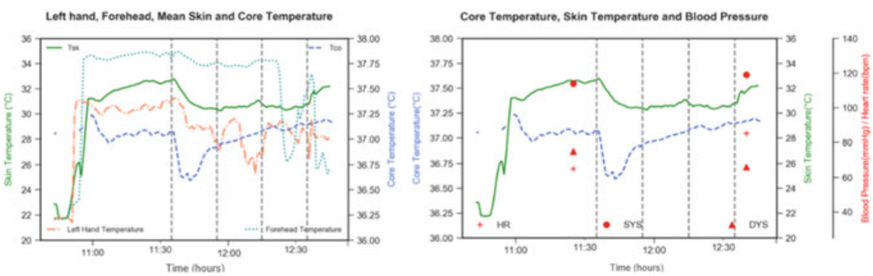

Fig. 1 Graphics models 1 and 2

Table 4 Blood pressure and Heart Rate results from participants

min	Blood Pressure (mmHg)						HR (bpm)		
	SBP			DBP					
	Mean	SD	min/max	Mean	SD	min/max	Mean	SD	min/max
20′	117.273	8.719	103/131	75.000	9.706	55/91	65.909	8.734	57/86
95′	119.454	10.699	96/133	68.636	7.567	50/77	75.000	14.697	**58/106**

3.1 Blood Pressure and Heart Rate

As evidenced within Fig. 1, HR and parameters of BP were measured before and right after exposure to SCE. Taking in consideration reference values from previous investigations [11, 12] and normative guidelines from the Portuguese General Health Department (DGS), mean values corresponded to healthy adults' ranges (Table 4). Mean results denoted a variation of approximately 2 mmHg, positive for SBP and negative for DBP, 5 min after exposure to SCE, compared to the initial measurements 10 min before exposure. The inverse relation between both outcomes is congruent with consulted literature [12], in which the usual response to exercise is indicated as an increase in SBP and no change or decrease in DBP. On the other hand, more significant differences were observed in HR outcomes as they revealed a mean increase of almost 10 bpm after exposure to SCE. Given the physical requirements of the protocol and the additional load from protective clothes, that elevation was justified.

3.2 Core and Skin Temperatures

Core temperature. Reference values from the International Organization for Standardization and limits established for occupational settings [7, 13] were considered when observing obtained data. Within results, temperatures permanently evidenced normal reference ranges. Variations were observed along the experience. However, they did not prove any alert level value. The most significant variation was observed after exposure to SCE, in which mean values decreased the most until a temperature of 36.996 °C. When submitted to SCE, participants evidenced mean T_{core} decreases in the first 10 min, but afterwards, T_{core} started increasing until the end of the exposure. This fact could be related to a higher metabolic heat production [14] and vasoconstriction [15]. Along the experience, the T_{core} variations were always less than 1 °C difference between the minimum and maximum value, in the most of the cases between 36.5 and 37.5 °C. In this study, both T_{core} and T_{skin} increased with higher physical exertion, even when exposed to SCE, and decreased with lower physical exertion even when exposed to comfort temperatures.

Table 5 T_{core} and T_{skin} results from participants

Phase	min.	T_{core}		T_{skin}		Left Hand T_{skin}		Forehead T_{skin}	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Before SCE	0	37.109	0.273	30.930	0.871	27.666	2.700	33.913	0.543
	30′	37.028	0.303	32.065	0.761	29.377	2.803	34.079	0.622
During SCE	50′	37.028	0.250	30.694	0.783	26.785	1.557	31.793	3.160
	70′	37.236	0.264	30.960	0.762	25.869	2.824	32.585	1.983
	90′	37.282	0.237	31.328	0.957	27.479	3.485	31.287	3.681
After SCE	180′	36.996	0.240	33.171	0.871	30.616	1.321	33.730	0.536

Skin temperature. As evidenced in Table 5, measured and mean-calculated T_{skin} increased in the first 30 min of the trial. Given the designed sequence of activities, this outcome was justified. The sensors were put on the volunteers without clothes. Afterwards, they dressed regular clothes which resulted in the first increase in temperatures. Ten minutes before exposure to SCE, the volunteers put on the cold protective clothing which resulted in the second rise of measured temperatures. Mean values of the left hand had the most significant decrease of all measured skin temperature points. In general, they decreased from 27.666 °C to 25.869 °C after 40 min of exposure to SCE. Afterwards, they started a slow rise which could have been associated with a more intensive manual hand heating. The temperature increased to 27.479 °C at the end of the exposure to SCE. The hand temperature recovery period took 20 min (without gloves). Notably, after the 90 min considered for the experience, mean values of temperature exceeded initial recordings and reached 30.616 °C. Correspondingly, the forehead also presented considerable temperature variations (the highest after the left hand among all the measured skin points). The temperature decreased throughout the exposure to SCE from 34.079 to 31.287 °C. The recovery period was 20 min after exposure to SCE. Overall, results of the calculated mean T_{skin} show a decrease from 32.065 to 30.694 °C in the first 20 min of exposure to SCE, which is not as low as a previous study conducted with a walking/jogging activity and a 60-minute exposure to −20.0 °C. Within the referred investigation, reported T_{skin} decreased to 27 °C. However, variations from initial values could not be retrieved since the study did not report baseline recordings [16]. Later on, T_{skin} had small increases, reaching 31.328 °C at the end of the exposure to SCE.

Thermal Sensation. Alterations on thermal sensation were recorded right after the beginning of exposure to SCE. The most significant outcomes were registered during the first 20 min of SCE as volunteers evidenced a thermal sensation (Question 1) between slightly cool and cool (mean obtained value: 1.54). Throughout the rest of time exposed to SCE, thermal cold sensation decreases and participants seem to experience a psychological adaptation to cold and higher thermal comfort. In general, answers to questions 1, 2 and 3 evidence correspondence with obtained values in T_{skin} before and during exposure to SCE. However, through the recovery period, there is a faster stabilization in the thermal sensation compared with the physical parameters.

4 Conclusions and Limitations

Throughout this study, some particular considerations can be highlighted. Firstly it was observed that: when cold sensation increases, so does pain sensations of the body parts where the skin temperature decreases. In this regard, validated TSQ models should be created adding more questions about thermal sensation on specific parts of the body, such as the ones included in this study. Finally, it was also observed that both, T_{skin} and T_{core}, increase with physical exertion even with exposure to SCE. Therefore, physical exertion is the primary parameter to consider when evaluating T_{skin} and T_{core} tendencies. Observing the limitations, the number of volunteers could have been higher in order to support the reliability of obtained results, although the selection of volunteers was strict and many potential candidates were excluded due to the selecting criteria: only male non-cigarette smokers. Additionally, when recording HR and blood pressure, more measurements could have been done in order to have a clearer perspective on the evolution of parameters, especially during exposure to SCE.

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Part IV
Ergonomics and Biomechanics

Postural Instability During Obstacle Crossing While Performing Manual Material Construction Handling Tasks

Rui Azevedo, Eduardo Abade, Nuno Teixeira, Alberto Carvalho and Maria Manuel Sá

Abstract Fall accidents are the most frequent accidents in construction industry and may result in serious injuries of workers involved. In order to prevent falls, it is important to understand the events leading to postural imbalances. This study aimed to investigate the impact of handling different objects during obstacle crossing in postural instability. Thirteen volunteer physically healthy subjects (age, 22 ± 1 years; body height, 177 ± 4 cm; body mass, 73 ± 7 kg) participated in the study. The experimental procedure was performed in a treadmill comprising three different tasks performed as follow: (i) walking with obstacle clearance without carrying a load, (ii) walking with obstacle clearance carrying cement bags 25 kg load (shoulder loading) and (iii) walking with obstacle clearance carrying a floor planks 18 kg load (shoulder loading). Mean force, force-time integral, pressure-time integral and contact-time of the stance foot were recorded. Additionally, the anterior-posterior and medial-lateral displacement of centre of pressure was evaluated. The results showed that handling different objects during obstacle crossing

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did not affect the postural stability. Thus, it seems that the technique of carrying a load in the shoulder does not impair the postural stability during obstacle crossing.

Keywords Ergonomics · Manual handling · Balance

1 Introduction

Occupational injuries are recurrent in construction industry, partly as a consequence of outdoor operations, working at heights [10, 14, 21, 25], exposure to weather, confined spaces and physical vulnerability [6, 10, 12, 21, 25]. Additionally, the equipment operation and the workers' attitude also contribute to increase the risk of accidents [10, 12, 22, 25]. Research classifies construction accidents in eight basic groups [11]: (i) falling from height, (ii) falling objects/moving vehicles, (iii) excavation related accidents, (iv) operations of machinery/tools related accidents, (v) electrocutions, (vi) fire/explosion, (vii) failure of temporary structure, and (viii) others.

Fall accidents are the most frequent accidents in building works and may result in serious injuries [1, 15, 21, 24]. The causes of fall accidents include design factors such as activity/task design and clothing/footwear and active failures like age and perceptual skills. Generally, five main factors may lead to fall accidents in construction labor: human, equipment, management, organizational and environmental factors [15]. Some authors suggest that fall accidents are frequent during the afternoon time because of working under physical and mental fatigue [11] and that these accidents may occur on areas of scaffoldings, ladders and working structure [15]. However, work time and construction location/terrain do not generate general agreement across research.

Previous researchers have found that fall accidents in construction industry represented more than 47% of total fatality in Hong Kong [5], 37% of death in USA [8] and 51% of injuries in China [26]. The direct effect of these accidents may result in multi-million losses every year. For example, the total health care costs due to work-related injuries in the Netherlands were 1.15 billion in 2004 [19], while the estimated indirect and direct costs linked to fall accidents in USA were estimated at six billion in 2000 [7].

Despite of the technological advances, there are several construction industry tasks that involve the manipulation of various items with different weight and size characteristics [17]. The size of the load and its handling may impair the worker's views and the postural balance, leading to falls, mainly during obstacle crossing [3]. To the best of our knowledge, literature points three options for obstacle clearance: step over, step on or circumnavigate the obstacle [4]. Among these, stepping over the obstacle seems the most frequent option used by workers on the construction site [3].

In theory, most construction injuries can be prevented or controlled. However, it has been a challenge to achieve this goal [21]. As a consequence, preventing falls must be a priority in the construction industry [16]. Understanding the events leading to postural imbalances in construction sites is vital to prevent falls and serious injuries. Thus, this study aims to investigate the impact of handling different objects during obstacle crossing in the postural instability.

2 Methods

2.1 Participants

Thirteen volunteer physically healthy subjects (mean age ± SD: 22 ± 1 years, body height: 177 ± 4 cm, body mass: 73 ± 7 kg) with no cardiovascular or orthopaedical problems. Subjects were informed on the research procedures before they gave informed consent.

A written consent form in accordance with the latest revision of the Declaration of Helsinki was also required so that this protocol would be approved by the ethics committee of the Research Centre in Sports Sciences, Health and Human Development (Portugal).

2.2 Procedures

During the tests, the subjects walked continuously on a four meter long treadmill (MIRALAGO make, built specially for the purpose) at a constant speed of 1.1 m/s (4 km/h), corresponding to normal gait speed. All participants considered the gait comfortable at this speed. Several trials were performed in construction sites comprising of normal gait on the floor with obstacle clearance. During these trials the subjects were instructed to walk a known distance at a self-selected velocity and the time spent by each subject was registered to calculate velocity. The results obtained by these trials confirmed the adequacy of the treadmill speed for the performance of trials. Three obstacles were placed on the treadmill belt, at variable time intervals and distances. A curtain was used to avoid obstacle anticipation during the gait process and hid the obstacles; consequently, subjects were not able to anticipate the obstacle position.

Prior to the tests, all participants performed walking exercises in order to get used to walking on the treadmill. The obstacles' heights were chosen according to daily activities in construction sites, as a result of direct observation of construction workers performing their tasks in loco. All obstacles had 45 cm (length) × 30 cm (width) × 10 cm (height). The subjects were instructed to step over the obstacles. To better simulate working conditions, all participants wore a safety helmet and safety boots. The participants wore a full-body safety harness, which was attached to a ceiling mounted hook to insure that subjects would not become injured should their recovery reaction be inadequate.

The experimental procedure comprised of three trials, with a maximum duration of 1 min and a half, in three different tasks performed by the following order:

- (i) walking on the treadmill with obstacle clearance without carrying a load;
- (ii) walking on the treadmill with obstacle clearance carrying cement bags 25 kg load (shoulder loading);
- (iii) walking on the treadmill with obstacle clearance carrying a floor planks 18 kg load (shoulder loading).

During manual material handling tasks, workers adopted a shoulder loading posture, which is quite common in the construction industry. The loading strategies were selected based on the information of eleven focus groups involving a total of 44 participants covering a range of six different stakeholders from the industry, such as Construction Site Supervisors, Ergonomists, Civil Engineers, Safety Engineers, Occupational Medicine Doctors and Health and Safety Coordinators. During the interview, each group was asked to consider the main strategies adopted by workers while performing manual material handling tasks in construction sites. This information was complemented with observation of manual material handling tasks in construction sites.

2.3 Data Collection

Gait analysis was performed by using the novel PEDAR in-shoe plantar pressure (100 Hz) measurement system (novel GmbH, Munich, Germany). After familiarization, subjects performed three trials. The Pedar-X software records the location of the in-shoe CoP as X–Y coordinates relative to an origin located at the most medial and posterior points of the insole. The in-shoe CoP was calculated as a graph of sampled points throughout the stance phase of gait. The displacement of the CoP in medial–lateral direction was defined by subtracting the lateral maximum by the minimum coordinates of the CoP during the one-leg stance. The same procedure was made for anterior-posterior displacement of the CoP [18].

Additionally, force (F), force-time integral (FTI), pressure-time integral (PTI) and contact-time (CT) were defined for the three tasks performed.

2.4 Statistical Analysis

Means and standard deviations were reported for X–Y coordinates, force (F), force-time integral (FTI), pressure-time integral (PTI) and contact-time (CT) at all three different tasks performed. One way analysis of variance (ANOVA) on all factors was performed for all dependent variables. Comparisons were made between load weight, load handling strategy and obstacle clearance variables. Pairwise post hoc analysis (Tukey's H.S.D. test) of the ANOVA results was performed to determine which means were significantly different from each other. Significant level was set at $p = 0.05$.

3 Results

Table 1 shows the mean and standard deviation results for all thirteen subjects, which was obtained during obstacle clearance with the support leg: CT; F; FTI; PTI.

In this study, we found statistical differences in force parameters as we expected because of the loads. So these differences are explained by the weights that subjects had to carry.

3.1 Lateral Displacement of Centre of Pressure

Table 2 shows the results of the lateral displacement of the centre of pressure. No differences were found between the three conditions. The medial–lateral displacement of the CoP in the three movements was identical (27 to 29 mm). However, a shorter displacement was found when subjects had to stepping over an obstacle with a cement bag.

3.2 Anterior-Posterior Displacement of Centre of Pressure

Table 2 shows the results of the anterior-posterior displacement of the centre of pressure. No differences were found between the three conditions. Nevertheless, carrying the cement bag resulted in the largest forward movement.

Table 1 ANOVA of the force, force-time integral, pressure-time integral and contact-time for the three conditions tested

	Without	Cement bag	Floor planks
Contact Time (s)	0.70 ± 0.08	0.69 ± 0.07	0.74 ± 0.11
Force (N)	539.62 ± 78.03*	665.90 ± 95.81*	627.34 ± 108.86*
Force Time Integral (N*s)	385.33 ± 67.98*	472.35 ± 98.63*	469.36 ± 117.51*
Pressure Time Integral (kPa*s)	148.57 ± 52.60	159.47 ± 52.49	170.60 ± 52.90

*Statistical differences between without and cement bag ($p < 0.05$)

Table 2 ANOVA of the medial-lateral and anterior-posterior displacement of

	Without	Cement bag	Floor planks
Medial-lateral displacement CoP (mm)	29.96 ± 9.46	26.92 ± 9.36	29.15 ± 8.96
Anteroposterior displacement CoP (mm)	128.12 ± 40.31	145.09 ± 25.09	138.12 ± 36.05

*Statistical differences ($p < 0.05$)

4 Discussion

The present study was performed to assess postural stability during obstacle crossing while performing handling tasks with material construction with participants adopting a shoulder loading posture, common in the construction industry. In this study, subjects had to step over obstacles without load and while carrying loads different sizes and weights. To perform this task successfully the subjects tried to avoid accidental contact with the obstacle.

According to the results, the weight and size of the material carried did not impaired postural stability. However, it is important to notice that carrying the cement bag resulted in the largest forward movement when compared to carrying the floor planks or no loads clearance. The durations of each one-leg stance that were obtained from this study are higher than walking, because subjects had to step over an obstacle. When carrying floor planks, the contact-time and the pressure-time integral were higher, however no differences were found. These results can be explained by the limitations of load weight, since there is an ergonomic limitation for the load carried by the individuals, although in construction sites workers usually handle heavier loads than those tested in this study [3, 13]. On the other hand, as expected, differences were found in the force and force-time integral when carrying loads.

Despite of the absence of differences, the larger forward movement of CoP was found when carrying a cement bag. This may be due to its weight and the instable position of the bag on the shoulder and the need to change gait path to better place the foot during obstacle clearance process [2, 3, 9, 23]. In fact, it appears that the higher the load the more significant may be the impact in postural stability. Previous research showed that an increase in the displacement of the CoP not only improves the magnitude of the electromyography, but also increases the number of muscles that are used in the lower extremities [20]. Moreover, the large displacement of COP results in a higher ankle torque and horizontal forces to restore the centre of gravity to a more balanced position [18].

5 Conclusions

During walking, postural balance is kept intact by a continuous effort of the musculoskeletal, visual proprioceptive or vestibular systems. This investigation aimed to understand the effects of obstacle clearance with and without carrying cement bags and floor planks on the postural stability in walking. According to the results, it is concluded that handling different objects during obstacle crossing did not affect the postural stability. Thus, the larger forward movement of the CoP carrying a cement bag can be due to increased weight and to the position of the bag during shoulder loading. Thus, it seems that the shoulder carrying technique does not impair the postural stability during obstacle crossing.

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Thermal Analysis of Musculoskeletal Overload in Vertical Handling of Loads in an Heterogeneous Sample

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Abstract Musculoskeletal injuries is presented as one of the occupational problems related to the vertical handling loads (VHL) performance. These tasks, including lifting and lowering, are very common in workplaces and present different musculoskeletal risk factors associated. One of these risk factors could be worker's body composition. Therefore, the main objective was to study the musculoskeletal overload during VHL in individuals with different body compositions. To accomplish that, it was used infrared thermography. Throughout, in this technique the skin temperature was measured before and after the task. Regions of interest (ROI) were defined in the shoulder area, considering that region is one of the most affect by VHL, and susceptible to work related musculoskeletal disorders (WRMSD). However, a total of sixteen ROI were defined, eight in the body anterior view, and eight in the posterior, and for each regions were analyzed minimum, maximum and mean temperatures were analyzed. In the selected ROI a cooling of the body surface after the task for the thermal variables was verified, which may increase the possibility of musculoskeletal problems. The data suggests that the increase of the worker's body fat may be related to the increase in cooling after the task, which indicates that obesity could be an important risk factor during VHL. Additionally, the infrared thermography seems to be a viable technique to assess the WRMSD risk.

Keywords Infrared thermography · ROI · VHL · Worker's body fat · WRMSD

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1 Introduction

The manual handling loads (MHL) is one of the main causes of severe musculoskeletal injuries worldwide and currently it is one of the most serious health problems in society [11]. In Portugal, the MHL is defined as any operation for the transport and support of a load by one or more workers who are frequently exposed to several risks, particularly to the back, due to the work places characteristics and/or work organization [25].

The MHL, which includes the vertical handling loads (VHL) can cause work-related musculoskeletal disorders (WRMSD), due to the biomechanical overload caused [7]. Normally, the WRMSD development has a cumulative nature, associated with repeated exposure to biomechanical *stress* during an extended period of time, affecting mostly the cervical region, shoulders and upper limbs, specifically, the arm, elbow, forearm, wrist, hand and fingers) and spine, with a higher incidence in the lumbar region. In VHL, the trunk and upper limbs are the principal body regions recruited, being the shoulder one of the body regions more susceptible to WRMSD appearance [8, 11]. In addition, WRMSD affects the worker's well-being, and can also interfere with their ability to perform the job functions. It is clearly demonstrated the association between the WRMSD absenteeism and reduces the reduction of productivity [27].

The risk of occurrence of LMERT is considered as multidimensional, since for its occurrence several factors contribute, such as psychosocial, individual, organizational and characteristics of the work station [20]. Accordingly to [8], risk factors can be grouped into three categories, specifically physical, organizational, and individual risk factors. Physical risk factors include work-related risks such as repetitive movements, frequent MMC, adopted posture, strength and static work, among others [13, 24]. As for organizational factors, as the name implies, these are related to the organization of work [8], such as the work and rest cycles, the absence of breaks, the performance of long-term shifts, and so forth [13]. Individual risk factors includes age, gender, clinical history, anthropometric characteristics, lifestyle and level of professional experience [8]. The anthropometric characteristics have been the object of analysis for several years, and there are contradictory studies about this subject [17], however there is consensus regarding the fact that these characteristics may contribute to the emergence of WRMSD [11].

The tasks of lifting and lowering loads (VHL), involve several muscle groups that contract and relax, performing muscular work. This whole process involves several physiological processes to which heat release is associated [22].

Infrared thermography (IT) is a technique that captures the natural radiation emitted by the surface of an object, whenever the temperature is above absolute zero. This technique relies on thermographic chambers with heat detection capability and is based on the sensitivity of the electromagnetic waves emitted by the human body, which reflects the molecular agitation of the tissues [18, 23]. This technique can provide important data and evidences for the diagnosis and treatment of various pathologies. IT is a noninvasive technique, not involving pain or discomfort for the participants, and does not use ionizing radiation [6, 18]. This technique (IT), presents numerous applications, namely in the diagnosis of musculoskeletal disorders, oncology, vascular disorders, arthritis, sports medicine and work, among others [23].

Therefore, the main objective of this study was analyze thermal differences resulting from the overload associated with VHL performance, considering individuals with different body compositions.

2 Materials and Methods

For the constitution of this sample it was necessary to select the participants in order to respect certain requirements, specifically, (i) age between 18 and 65 years (active age), (ii) absence of history of musculoskeletal problems, (iii) absent of scars in the selected body regions. Prior to the collection of data, the document of the free and informed consent was delivered to each individual participant

The collection of data was carried out in a laboratorial context, with specific conditions, namely, temperature (18–25 °C) and relative humidity (<60%), since these factors can influence the thermographic data [3, 9]. For this study it was necessary to collect information about participants, such as, age, gender, anthropometric data (body mass index-BMI-, abdominal perimeter-AP- and body fat mass %FM). To collect %FM a body fat monitor BF 306 Omron was used. The sample was categorized according to the personal data, as described in Table 1.

The handling task studied was defined considering the recommendations provided by the Portuguese legislation [25], as well as by the NIOSH'91 equation [29]. Therefore, the task comprises the manual lifting of a load weighing 7 kg from the ground to shoulders height and consequent lowering of the load, in the presence of a physical barrier, during a time period of 2 min with a repetition of 7 in 7 s. A plastic box with the dimensions of 38 × 28, 5 × 23 cm, with good handles, and a weight symmetrically distributed was used.

The thermographic camera used was FLIR E-60, that is an uncooled and portable camera with manual focus, color screen, focal plane array of 320 × 240, and the images are collected in JPEG® format [10]. Prior to the collection of the thermograms it was necessary set the temperature in the range 24–38 °C, and define the emissivity at 0.98. In order to insure the reliability of the thermographic data it was necessary respect requirements; namely, participants have to avoid smoking, eat and drink at least two hours before the experiment. To collect thermographic data it was necessary a period of acclimatization of 15 min with no cloth and hair in

Table 1 Categorization of the variables BMI, AP and %FM

Variables	BMI	AP	%FM
Groups	Normal Overweight Obesity	Normal Risk	Normal High Very high

the trunk area, in a relaxed position and do not cross arms or touch on back [3, 16]. First the anterior termogram (front view) was collected, and then the posterior (back view) and after the task both thermograms were collected, anterior and posterior.

To the thermograms analysis the software Thermal Cam Researcher Professional 2.10 FLIR Systems® was used. The 16 regions of interest (ROI) were defined, 8 for each view, anterior and posterior, according to the Glamorgan protocol [1, 2]. The ROI selection was based on the body regions frequently affected by WRMSD during VHL tasks [14], and avoiding areas with greater fat deposition, such as the abdominal area [19]. In the anterior view the ROI are included in the shoulder joint, upper ligaments and lower ligaments of the shoulder, and arm; in the posterior view the ROI are in shoulder joint, neck, trapezius muscle and arm. Each ROI have a specific geometric form and instructions for the drawing [1, 2]. After the drawing of the ROI three thermal variables were measured, such as, minimum, maximum and mean (avg) temperature and standard deviation (sd) for each ROI. With this data it was possible to calculate the temperature variation (ΔT) after the task performance, as defended by Formenti et al. [12], for the 3 thermal variables. The thermal symmetry was also verified, by the difference of the mean temperatures of contralateral ROI, and this value cannot exceed 0.5 ± 0.3, as defended by Govindu and Babski-reeves [16], Vardasca et al. [28]. To the statistical analysis the software IBM® SPSS® statistics 24.0 was used, and the following tests were used, Shapiro-Wilk (to check the data normality), Pearson's correlation (in order to verify the associations between BMI, AP and %FM and to verify the correlation between the temperature variation of each ROI and the BMI, AP and %FM of the participants). It was already used the t-test for paired samples (in order to verify if this difference between the temperatures recorded before and before the task, for the anterior and posterior RA, was significant) and ANOVA (to verify if there was a temperature variation considering groups determined by body composition assessment techniques, specifically BMI, AP and %FM).

3 Results

The sample was composed by 26 participants, 16 men and 10 women, with mean age of 34 ± 9.78 years, AP of 89.1 ± 14.2 cm, %FM of $23.2 \pm 8.48\%$, and BMI with a minimum of 18.5 kg/m^2 and a maximum of 38.7 kg/m^2. Regarding to the laboratorial conditions, the temperature recorded was 23.2 ± 1.2 °C and relative humidity $58.2 \pm 1.8\%$. Concerning the thermal symmetry it was verified that de reference values (0.5 ± 0.3 °C) [16, 28] were not exceeded, which indicates the absent of MSD in the body regions considered.

For the analysis of ΔT, the anterior and posterior data were analyzed separately, in both views the values of the thermal variables (minimum, maximum and mean), decreased after the task, as in Baker et al. [4], Gold et al. [15] and Govindu and Babski-reeves [16]. However, this difference before and after the task was not significant in all anterior ROI.

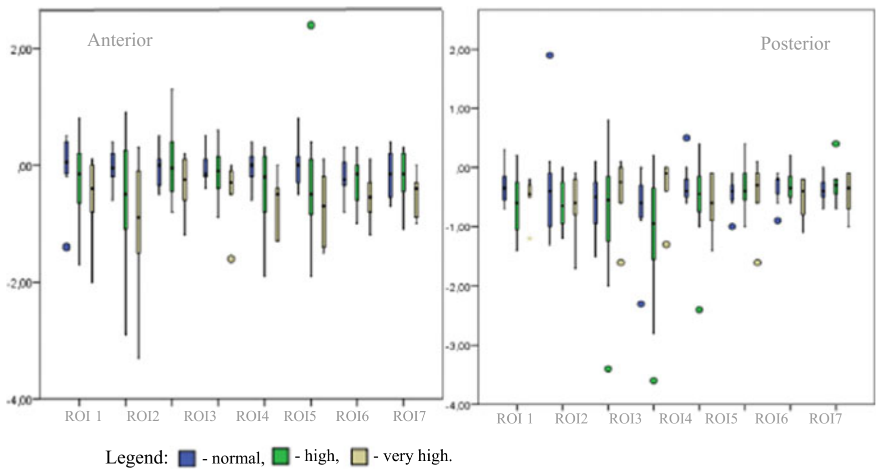

Fig. 1 Variation of the minimum temperature, anterior and posterior, by ROI considering the classification of %FM

In minimum ΔT the differences between the groups (%FM, AP and BMI) were significant, which was not observed in the posterior view. It was verified that overweight and obese individuals (%FM) present higher cooling of the ROI, when compared to normal individuals, as presented in Fig. 1. Individuals with excessive visceral fat (risk at AP) have greater cooling in the studied ROI, and considered BMI groups it was verified that obese individuals have higher cooling than individuals with excess weight and, in turn, they have a greater cooling than normal individuals.

In ΔT maximum, for the groups defined by %FM and AP, the differences weren't significant, but for the anterior ROI's, individuals with high and very high obesity levels present higher cooling than non-obese individuals.

In ΔT mean, the differences weren't significant for the posterior ROI for the groups defined by %FM and AP. However, for the anterior ROI it was observed that individuals with a very high level of obesity (%FM) presented higher cooling than non-obese individuals, and individuals at risk (AP) present higher cooling than non-obese. Considering BMI groups, it was found that anterior and posterior ROI suffered cooling, so obese individuals exhibited a higher cooling than overweight and this a higher cooling than normal individuals.

4 Discussion

Govindu and Babski-reeves [16], defended the reliability of thermographic data and found a relationship between temperature variation (considering the body region of the deltoid muscle) and changes in task demands considering tasks of screwing with the arms elevated above the head in individuals with normal BMI (18.5–24.9 kg/m^2). According to the current results it was found that the infrared thermography technique identifies the variation of the occupational conditions after the VHL task, as identified by Bertmaring et al. [5] and Govindu and Babski-reeves [16].

Regarding the thermal variables, recorded before and after the VHL, a skin cooling was observed, with statistically significant differences for the three variables in the posterior view ROI and for the mean temperature of the anterior ROI, in the sense that the increased of workers' %FM may be related to the increase cooling after the task. Regarding the minimum and maximum temperatures of the anterior ROI, the differences verified were not statistically significant. In this study, the sample heterogeneity may have contributed to the variability between the groups considered, as well as the reduced number of statistically significant correlations. In the results related to ΔT, the skin cooling of the anterior and posterior ROI's was verified when considering the different techniques of body composition assessment covered in this study. Significant correlations were identified in ROI when considering the three forms used to classify body composition (%FM, AP and BMI), which indicates that these parameters show relevance for the possibility of increased musculoskeletal overload in performing VHL tasks. Although the temperature variation recorded was negative, with cooling, the statistical correlation between ΔT and %FM, AP and BMI was low. Considering the AP, Pryce and Kriellaars [21] verified that the increased of workers' abdominal mass, leads to the displacement of the body center of mass, which in the presence of the physical barrier (as considered in this study), causes the increase of the horizontal distance between the load and the workers' body, being this a risk factor for the WRMSD development associated with VHL [29].

Probably, and based on evidence from previous studies, namely Tanimoto et al. [26] and Williams and Warwick's [30] knowledge, this cooling, detected by the thermography technique used, results from vasoconstriction that occurs during muscle contraction, increasing the possibility of WRMSD development. Thus, considering the results obtained in this study, it is assumed that workers' excessive weight, AP and %FM potentiate the increase of ROI cooling.

5 Conclusions

According to the results obtained in this study, the occurrence of thermal symmetry between the contralateral ROI considered was observed, which indicates the absence of MSD in the body regions considered (a necessary requirement for participation in this study). Thus, the infrared thermography technique can be considered as a valid method of risk assessment of WRMSD in manual handling loads tasks, namely for VHL tasks. In addition to making it possible to identify pathologies, this technique can help to control the WRMSD development. It is noteworthy, although overweight and obesity seems to be related to a greater cooling of the skin surface in the considered ROI, which indicates that these individuals are more susceptible to the development of WRMSD. Thus, in order to prevent the occurrence of WRMSD, it is necessary, first of all, to focus on a culture of occupational health, adopting preventive measures regarding obesity. In addition, consideration should be given to adapting the jobs to the workers, considering the probable anthropometric changes that may arise associated with this increasingly common problem, obesity.

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Alternative Method to Predict Thermal Sensation Votes in Closed Environments

Evandro Eduardo Broday and Antonio Augusto de Paula Xavier

Abstract The PMV (Predicted Mean Vote) is an index that intends to predict the thermal sensation of people exposed to the same environment. However, there are discrepancies between the PMV model and the thermal sensation responses collected in field studies. In order to verify this question, this study had as purpose to present an alternative method to predict thermal sensation votes (TSV) by means of multiple regression between the votes of thermal sensation collected in field study, the metabolic rate and the mechanisms of heat exchange. For this study, data collection was performed with a group of women working at the office performing sedentary activities. When people vote for the neutrality (TSV = 0), PMV_{new} corresponds to 0.1165 (between "neutral" and "slightly warm" in a seven-point scale), thus showing the responses of thermal sensation closer to reality when comparing to the traditional PMV.

Keywords Thermal comfort · Predicted mean vote · Discrepancies

1 Introduction

In a work environment, whatever the activity developed, quality of life is an important factor not only for the expected results to be achieved but also for the employee. The quality of the activity performed reflects the state of the body and the mind of the people and the well-being in the development of the activities generates benefits for all.

In this sense, Ergonomics becomes relevant so that improvements in the work environment are obtained. Since its inception, Ergonomics has always focused on adapting the working environment to man. Hendrick [1] studied the concepts of

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Macroergonomics: worker's well-being continues to be a concern of the company, but now, concerns must be expanded beyond the man-machine interface, and consideration is also given to the environment in which the employee performs these activities. This new chain focuses on the development and application of human-machine interface technology throughout the organization, seeking to improve the organizational structure and processes related to work systems [2].

In the work environment, if the temperature is not adequate for the development of the activities, there may be discomfort and decrease in the performance of the people that are working in this environment [3]. In this way, Thermal Comfort studies are important, since better understanding of the thermal environment and what is needed to provide an environment where more people feel comfortable thermally is essential for optimizing the resources.

According to Yao et al. [4], the thermal comfort standards determine the energy consumption in a building's environmental systems; therefore, they play an important role in building sustainability. To measure the thermal sensation of a large number of people occupying an environment, the PMV (Predicted Mean Vote) index was proposed by Fanger in 1970 [5].

However, when this index is compared with the actual thermal sensations reported by people in the field studies, differences occur. Humphreys and Nicol [6], De Dear et al. [7], Maiti [8], Gilani et al. [9] and Li et al. [10] claim that the thermal responses obtained are not a match with the model.

By means of a multiple linear regression between the votes of thermal sensation collected with a group of women performing sedentary activities, the metabolic rate and the six mechanisms of heat exchange, this work aims to propose an alternative method instead of the traditional PMV, in order to get the thermal sensation responses closer to reality.

2 Materials and Methods

2.1 Characterization of the Sample

The group consisted of a 100% female population performing sedentary activities, most notably office services at the Faculty of Engineering of the University of Porto (FEUP), in the city of Porto, Portugal. With this group, a set of 48 measurements were collected (48 samples of environmental and personal variables). In this case, the environments analyzed had a central air conditioning system. Four different service units were analyzed: the Health, Safety, Hygiene, and Environment Unit; the Project Accountability Division; the Academic Services Division and the Division of Image, Communication and Cooperation Services.

Although this data collection has been performed in different service units, all evaluated workers performed a sedentary task, working on computers.

3 Acquisition of the Environmental and Personal Variables

The environmental data (air velocity, air temperature, mean radiant temperature and relative humidity) were recorded by the equipment *DeltaOHM*®, in intervals of 15 s, characteristic that was already predefined. Before the measurements were started, the equipment was set to reach thermal equilibrium with the environment 20 min. The equipment was positioned in accordance with ISO 7726 [11]: height of 1.10 m.

Workplaces were relatively small and people were very close to each other, so the equipment was placed in the center of each room so that it was close to all occupants of the environment. The center of the room was also the most representative point for collecting data.

Because it was a sedentary activity, the value used for the metabolic rate was 70 W/m^2. This value was obtained by ISO 8996 [12], and according to Yun et al. [13], for adults performing sedentary activities, the values of ISO 8996 (2004) represent a good approximation to reality.

Personal and individual variables were obtained through a questionnaire, which during the measurements, people were invited to complete. In this questionnaire, people were asked to fill in their personal information (age, height and weight), to describe the clothes they were wearing (according to ISO 9920 [14]) and how they were feeling, according to the index on the seven-point thermal sensation scale presented in ISO 7730 [15] (+3 = hot, +2 = warm, +1 = slightly warm, 0 = neutral, −1 = slightly cool, −2 = cool, −3 = cold). People's thermal sensation, that is, the way they were feeling during their activities, was named TSV (thermal sensation vote) in this research.

After acquiring all data, the statistical treatment of data was performed with the aid of the statistics software SPSS® 23, at a level of 95% reliability.

4 Proposition of the Alternative Method

The approximation used in this study was a multiple regression between the votes of thermal sensation reported by people during the data collection, the metabolic rate and the mechanisms of heat exchange between man and the environment, according to the Eq. (1):

$$PMV_{new} = aM - bC - cR - dE_d - eE_{sw} - fC_{res} - gE_{res} + h \tag{1}$$

where:

PMV_{new} = New Predicted Mean Vote;
a, b, c, d, e, f, g, h = estimators of the multiple regression;
M = metabolic rate (W/m^2);

R = heat flow by radiation (W/m^2);
C = heat flow by convection (W/m^2);
E_d = loss of latent heat by way of water vapor diffusion (W/m^2);
E_{sw} = loss of latent heat by sweat evaporation (W/m^2);
C_{res} = heat flow by respiratory convection (W/m^2);
E_{res} = heat flow by respiratory evaporation (W/m^2).

The thermal sensation votes reported by people, TSV, is the model dependent variable, and the metabolic rate and all heat exchange mechanisms are the independent variables of the model. After acquisition of the values, the following hypotheses were applied:

(a) H_0: $\beta 1 = \beta 2 = \beta 3 = \beta 4 = \beta 5 = \beta 6 = 0$ (Does not have a linear relationship);
(b) H_1: $b1 \neq 0$ or $b2 \neq 0$ or $b3 \neq 0$ or $b4 \neq 0$ or $b5 \neq 0$ or $b6 \neq 0$ (Has a linear relationship).

The hypothesis test was applied to verify the validity of the model and the multiple regression estimators, by verifying the linearity among the dependent and the independent variables.

In order to verify if the PMV_{new} is more efficient, the traditional PMV will also be calculated and compared with the thermal sensation votes collected in field studies. In both cases, a simple linear regression model will be used.

5 Results and Discussion

Thirty women, who were divided among the four service units analyzed, took part as volunteers of this research. The average age of these collaborators is 38.77 years, average weight of 65.38 kg and average height of 1.62 cm. Forty-eight measurements were performed, passing through the 4 service units analyzed. Table 1 presents the mean and standard deviation of the 48 measurements:

By using the environmental and personal variables collected, for the set of 48 measurements, the Kolmogorov-Smirnov normality test was applied (95%) with the use of the SPSS® 23 software and the normality of data was confirmed.

The approximation used was the multiple linear regression between the votes of real thermal sensation (TSV) reported by people, the metabolic rate and the six mechanisms of heat exchange. However, before performing the multiple regression,

Table 1 Mean and standard deviation (STD) for the personal and environmental variables

	Air Temp. (°C)	Mean Radiant Temp. (°C)	Air velocity (ms^{-1})	RH (%)	Metabolic rate (Wm^{-2})	Clothing Insulation (clo)
Mean	21.77	21.24	0.02	45.74	70.00	0.95
STD	0.73	0.66	0.02	7.27	0.00	0.07

it was necessary to determine each of the heat losses. Table 2 presents these calculated values.

As can be seen in Table 2, the TSV variable is the dependent variable and the metabolic rate and the six heat dissipation mechanisms are the independent variables of the model. After having these data calculated, the multiple regression, which provided Eq. (2), was performed through SPSS software:

$$PMV_{new} = 13.414 + 0.256\mathrm{C_{res}} - 5.314\mathrm{E_{res}} + 1.923\mathrm{E_d} - 0.135\mathrm{R} - 0.169\mathrm{C} \quad (2)$$

Statistical summary of the multiple regression that generated Eq. (2) is shown in Table 3:

On comparing the model variation with the residues variation taking heed that the relationship has the Fischer-Snedecor distribution. Therefore, with $\alpha = 0.05$ it was verifiable that $F_{critical}$ with 5 and 42 freedom degrees is equal to 2.44 [16]. $F_{calculated}$ by the model is 8.675. As the $F_{calculated}$ is extremely higher than $F_{critical}$, H_0 hypothesis is declined. Since this information is confirmed, it is possible write Eq. (2) in terms of environmental and personal variables, generation Eq. (3):

$$\begin{aligned}\mathrm{PMV_{new}} &= 13.414 - 0.00003584\mathrm{M}(34 - \mathrm{t_a}) + 0.092.\mathrm{M}.(5{,}87 - \mathrm{p_a}) \\ &- 5.87(5.73 - 0.007[\mathrm{M} - \mathrm{W}] - \mathrm{p_a}) - 0.53 \times 10^{-8} \cdot \mathrm{f_{cl}} \cdot [(\mathrm{t_{cl}} + 273)^4 - \left(\mathrm{t_{rm}} + 273)^4\right] \\ &- 0.169\mathrm{f_{cl}} \cdot \mathrm{h_c} \cdot (\mathrm{t_{cl}} - \mathrm{t_a})\end{aligned} \quad (3)$$

In the intent to verify if improvements in the relation between the responses on thermal sensation and the new model occurred, $\mathrm{PMV_{new}}$ was determined by using Eq. (3) and a simple linear regression between TSV and $\mathrm{PMV_{new}}$ was performed, as shown in Fig. 1.

$\mathrm{PMV_{new}}$ and TSV are related according Eq. (4):

$$\mathrm{PMV_{new}} = 0.5078(\mathrm{TSV}) + 0.1165 \quad (4)$$

According to Eq. 4, it's possible to verify that when people vote for the neutrality option (TSV = 0), the $\mathrm{PMV_{new}}$ corresponds to 0.1165 (between "neutral" and "slightly warm" in the seven-point scale).

In the intent to compare $\mathrm{PMV_{new}}$ with the traditional PMV, a simple linear regression between TSV and PMV was performed, as shown in Fig. 2.

PMV and TSV are related according Eq. (5):

$$\mathrm{PMV} = 0.0543(\mathrm{TSV}) + 1.74 \quad (5)$$

According to Eq. 5, it's possible to verify that when people vote for the neutrality option (TSV = 0), the PMV corresponds to 1.74 (between "slightly warm" and "warm" in the seven-point scale). This result, in which the PMV equation

Table 2 Calculated values of heat losses to perform the multiple regression

	TSV	M	C_{res}	E_{res}	E_d	E_{sw}	R	C
1	0	70	1.31	5.41	11.71	4.98	26.25	23.88
2	0	70	1.26	5.36	11.58	4.98	26.39	22.58
3	0	70	1.28	5.44	11.79	4.98	25.30	23.53
4	0	70	1.25	5.43	11.76	4.98	26.14	22.28
5	−2	70	1.29	5.40	11.69	4.98	29.86	26.77
6	−0.25	70	1.23	5.31	11.45	4.98	28.88	25.05
7	0.33	70	1.22	5.39	11.64	4.98	25.49	21.65
8	0.33	70	1.21	5.32	11.49	4.98	26.14	22.03
9	0.25	70	1.23	5.39	11.65	4.98	27.13	22.62
10	0.5	70	1.17	5.29	11.41	4.98	25.93	21.22
11	0.25	70	1.20	5.37	11.60	4.98	26.06	22.13
12	1.25	70	1.18	5.32	11.48	4.98	25.49	21.61
13	0	70	1.21	5.79	12.66	4.98	26.78	20.51
14	−0.3	70	1.24	5.83	12.77	4.98	25.06	23.18
15	0	70	1.19	5.84	12.78	4.98	27.40	21.37
16	0	70	1.14	5.82	12.73	4.98	24.37	18.94
17	0	70	1.30	5.91	12.97	4.98	27.33	21.28
18	2	70	1.19	5.89	12.91	4.98	24.25	18.56
19	0.3	70	1.16	5.81	12.72	4.98	24.49	18.57
20	0.14	70	1.11	5.71	12.46	4.98	24.23	18.99
21	0.1	70	1.20	5.85	12.80	4.98	26.82	20.12
22	1.2	70	1.12	5.79	12.66	4.98	25.61	18.37
23	−0.13	70	1.16	5.69	12.40	4.98	25.30	19.63
24	0	70	1.13	5.62	12.22	4.98	24.33	18.21
25	0	70	1.28	5.90	12.93	4.98	27.81	23.23
26	0	70	1.20	5.88	12.88	4.98	28.27	19.61
27	−0.33	70	1.20	5.79	12.66	4.98	27.76	21.59
28	−0.44	70	1.19	5.75	12.55	4.98	27.07	22.28
29	0.5	70	1.20	5.51	11.95	4.98	29.19	21.34
30	0.57	70	1.15	5.42	11.72	4.98	27.94	20.60
31	0.5	70	1.12	5.40	11.67	4.98	27.42	19.37
32	0.5	70	1.07	5.37	11.61	4.98	26.98	18.80
33	0.43	70	1.19	5.54	12.04	4.98	27.20	20.99
34	0.44	70	1.12	5.53	12.01	4.98	26.39	19.31
35	0.86	70	1.10	5.60	12.18	4.98	26.15	19.42
36	0.71	70	1.12	5.61	12.22	4.98	24.39	23.92
37	−0.67	70	1.42	5.91	12.95	4.98	29.50	23.75
38	0	70	1.37	5.87	12.87	4.98	26.84	23.48
39	1	70	1.24	5.86	12.83	4.98	24.87	20.02
40	0.33	70	1.25	5.84	12.79	4.98	25.92	20.32

(continued)

Table 2 (continued)

	TSV	M	C_{res}	E_{res}	E_d	E_{sw}	R	C
41	0	70	1.25	5.98	13.13	4.98	27.95	20.71
42	1	70	1.15	5.89	12.91	4.98	25.87	17.55
43	1	70	1.15	5.86	12.85	4.98	25.04	19.50
44	1	70	1.12	5.81	12.71	4.98	25.10	18.07
45	−0.33	70	1.24	6.00	13.19	4.98	28.91	20.45
46	0.25	70	1.17	5.91	12.98	4.98	25.83	19.26
47	1	70	1.11	5.85	12.82	4.98	25.30	18.22
48	1	70	1.12	5.84	12.78	4.98	24.91	19.22

Table 3 Statistical summary, PMV_{new}

R	R^2	F Change	df1	df2
0.713	0.508	8.675	5	42

Fig. 1 Relation between the TSV and PMV_{new}

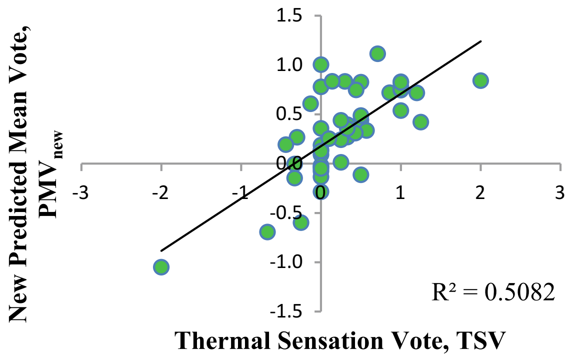
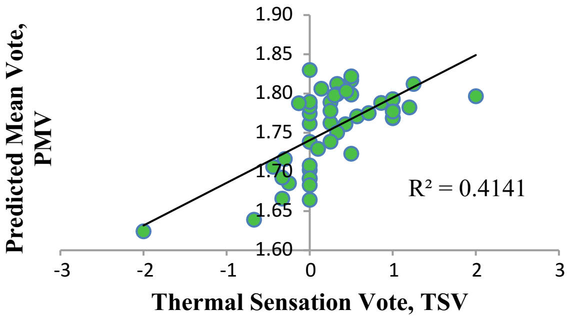


Fig. 2 Relation between the TSV and PMV



predicts more heat than people actually feel, was also found by Feriadi [17] in residences and Indraganti [18] in university classrooms.

Despite the moderate coefficient of determination, Eq. (4) is able to predict thermal sensation votes closer to the reality of the environment, when people in the studied environment are performing sedentary activities, the case of this study.

6 Final Considerations and Study Limitations

In emerging economies such as Brazil, China, and India, the number of air-conditioned households has increased dramatically, increasing demand for energy. So, an environment that does not provide Thermal Comfort for most of its users forces them to seek alternative energy sources to achieve comfort, making energy use grow.

When people voted in “neutral”, the prediction equation presented in this study showed that the vote is 0.11, a value much closer to the “neutral” in the seven-point scale, when comparing to the traditional PMV (1.74).

In environments where other kinds of activities are performed, such as heavy-duty work, sports and domestic tasks, it could be that the results found in this study may not suitably represent analysis and thermal comfort predictions.

It is also known that might be a probability of imprecisions in clothing thermal insulation (Icl). The values were consulted in ISO 9920 (2007) and due to the great amount of clothing, it was not always possible to obtain an exact value for each piece of clothing. PMV_{new} is applicable for the thermal conditions presented in this study: for people performing sedentary activities (metabolic rate in 70 W/m^2). For future studies, a suggestion is performing this study in non-sedentary activities.

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Ergonomic Assessment of a Wire Terminal Crimping Workstation

André Cardoso, Jorge Faria, Ana Colim and Paula Carneiro

Abstract The present study provides an ergonomic assessment of a wire terminal crimping workstation in a wiring manufacturing company for the automotive industry. It aims to evaluate the WMSD risk. To provide this assessment two methods were used: EWA and RULA. The first show us that the main problems were postures and movements, work content, repetitiveness of work and the thermal environment. The second show us that the worst body posture and movements were in the arms, forearms, wrist and trunk. The results show that there is a need to mitigate the problems encountered, so we suggested two kind of measures: engineering measures (presenting a redesign of the workplace using anthropometric data) and organizational measures.

Keywords Ergonomics · EWA · RULA

1 Introduction

Ergonomics focuses in the relationship between the worker and the working conditions, concerning the postures and body movements, work equipment, environmental factors (noise, vibrations, thermal environment, lighting, chemical agents), tasks performed and physical characteristics of the workstation [1]. The problems related with this subject are frequently ignored among industries. Due to this, in industrialized societies, the musculoskeletal disorders (MSD) have progressively increased, resulting in significant costs [2].

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MSD are inflammatory and degenerative diseases that affect the locomotor system. These are defined as lesions or diseases of muscles, nerves, tendons, ligaments and cartilage [3]. According to Eurostat [4], these work related disorders affect 60% of work population. In Portugal, the risks associated with body postures are those with a higher score (115 points in 140), slightly above the European average (100 points) [5]. Symptoms usually include pain (especially localized in a body region), numbness of the limb, feeling of heaviness, fatigue, loss of strength, and local swelling. These symptoms gradually appear, aggravating at the end of the working day or during peak production and reducing with breaks and holidays [6]. When MSD are originated from work or are aggravated by the same are called work-related musculoskeletal disorders (WMSD).

The main WMSD risk factors are: the repetitive tasks, the application of force and the awkward postures [2]. This makes relevant an ergonomic assessment whenever one of these situations occurs. To carry out this assessment different methods and techniques are referred in the scientific literature [7].

In this study, in order to assess the WMSD associated to a wire terminal crimping workstation in a wiring manufacturing company for the automotive industry, the following methods were applied: ergonomic workplace analysis (EWA [8] and the rapid upper limb assessment (RULA) [9]. The main goal is to evaluate the WMSDs risk, as well as to present recommendations for any problems encountered.

2 Characterization of the Workstation

The company under study is engaged in the production of cabling for the automotive industry. The workstation studied is inserted in the production section and the work activity consist in the crimping of wire terminals. It has been found that the machine operates with the guards lifted and its position on the on the bench forces the worker to adopt inappropriate positions. In addition, the chair used by the workers is not adjustable. It was also registered that there are several complaints of back pain, maybe caused by the awkward postures adopted during work activity. The work shift is 8 h and there is 10 min break every two hours. In this production section six workers of both genders were observed.

Concerning the environmental conditions, the physical measurements revealed the following results: Illuminance: 330 lux; Predicted Mean Vote Index (for thermal environment): PMV = 1.26 (meaning that the thermal condition is category 1: hot); Sound pressure level of daily exposure—($L_{ex8h):}$ 74.4 dB (A). Vibrations and chemical agents were not evaluated because the workers were not exposed to any of its. This data was obtained though internal reports.

Relatively to the tasks, primarily the workers place the wires on the support of the crimping machine, reach the terminals and place them in bundles of wires (3–9 kg). Then, pressing a pedal, it pins the terminals in the wires. When the terminals are embedded to the wires, the workers place them in a box which is beside them, on the floor. The workers adopted a sitting posture using a slightly adjustable wooden chair. During the work activity, the legs and feet are well supported. The mentioned tasks are repeated for more than 4× per minute.

3 Methodology

In a first stage, the EWA was applied in order to study different occupational conditions which can interfere in the ergonomic quality of the workplaces. This method does a general approach to the work activity, allowing the intervention actions to be prioritized for the parameters with the most severe score (FIOH 2015). This method gives an overview of work physiology, occupational biomechanics, information psychology, industrial hygiene and socio-technical modelling of the organization of work [8]. It is an observational method where the analyst gives a score between 1 and 4 or 1 and 5 according to the items in analysis. For each item, the workers' perceptions were collected applying the following scale: very bad (−−), bad (−), reasonable (+) or god (++). There are 12 items, namely: workspace, general physic activity, lifting tasks, postures and movements, risk of accidents, content of work, restrictiveness of work, communication of the worker, repeatability of work, attention required, illumination, thermal environment and noise (FIOH 2015).

Then the WMSDs risk was evaluate by RULA. With this purpose, the most critical postures were selected throughout direct observation and video recording. This method is used to evaluate posture, strength and movements associated with repetitive manipulation tasks. It is divided to evaluate two different groups, A and B. Group A includes arm, forearm and wrist while group B includes the neck, trunk and legs. The score is attributed consonant the posture of each body part in analysis. For this assessment is also given a score for muscle effort and force/load. The final step, with the score for each group, is to use a matrix to obtain the final score [9]. Finally, considering the risk factors identified different ergonomic recommendations were proposed.

4 Results and Discussion

The EWA results showed that there is not a very marked discrepancy between the evaluation performed by the analyst and the worker assessment. Both agree that the most painful scores (4 and 5 on a scale of 1–5) in this workstation are: postures and movements; work content; repetitiveness of work; and the thermal environment. The postures and movements are mainly due to poor organization of the workstation, since the necessary material is out of workers' reach, forcing the adoption of awkward postures to achieve the material needed (with arms and shoulders elevation and trunk flexion with lateral inclination). In addition, the chair used does not present an adequate back support. Regarding the content of work, the worker spends 8 h to pin terminals on the wire, being that the choice of which terminals and which wires should be use became from superiors. The repetitiveness of the work is explained because the worker repeats the same movements (pin terminals in the wire, once nailed, put wire with terminal in a box next to him) throughout the entire shift. Finally, regarding to the thermal environment, in a previous study has been suggested corrective measures, since the air conditioning is ineffective, existing several workers' complaints about this factor.

In addition to these parameters, the worker also considered "bad" the risk of accidents and noise, and the analyst assigned a score of 3 points to these two parameters. The risk of accidents is due to the fact that the crimping of the terminals takes place with the protection of the machine raised. And the noise will be due to the operation of other workstations, because the location of this workstation is shared with other production stations. These results are summarized in Table 1.

Since the EWA results allow us to overview the points of the workplace and prioritize the ones that need a quick intervention due to the critical score, it was decided to apply the RULA method, mainly due to the high repetitiveness of the work station and to incorrect postures and movements.

For the analysis of group A (upper limbs and wrist), a score of 6 values was obtained, since the worker flex the arm about 20° with abduction, the forearm flex more than 90° and the wrist is bent around 15° with slight lateral flexion and rotation. While for analysis of group B (neck, trunk and lower limbs) the score was 7 values, as the neck flex 20° with lateral inclination, the trunk flex about 20° with laterally inclination and poorly supported, and the legs and feet are well supported (Table 2). Through this first analysis it was verified that the body segments with more critical scores were the arms, forearms, wrist and trunk. This is justified for the incorrect positions that the worker adopts.

Table 1 EWA results according to the analyst and the worker

Parameter	Evaluation by the analyst	Evaluation by the worker
1—Workspace	3	+ (reasonable)
2—General physic activity	2	+ (reasonable)
3—Lifting tasks	1	++ (good)
4—Postures and movements	4	−− (very bad)
5—Risk of accidents	3	− (bad)
6—Content of work	4	− (bad)
7—Restrictiveness of work	2	+ (reasonable)
8—Communication of the worker	2	+ (reasonable)
9—Difficulty making decisions	1	++ (good)
10—Repeatability of work	5	−− (very bad)
11—Attention required	2	+ (reasonable)
12—Illumination	1	++ (good)
13—Thermal environment	4	− (bad)
14—Noise	3	− (bad)

Table 2 RULA results and example of a worker posture

Steps	Score	Worker posture
1—Upper arm position	3	
2—Lower arm position	3	
3—Wrist position	3	
4—Wrist twist	1	
5—Calculate the score for group A	4	
6—Add muscle effort score	1	
7—Add force/ load score	1	
8—Group A score	6	
9—Neck position	3	
10—Trunk position	5	
11—Legs	1	
12—Calculate the score for group B	5	
13—Add muscle effort score	1	
14—Add force/ load score	1	
15—Group B score	7	
Final score	7	

Then, a final RULA score of 7 points was obtained, indicating an action level D. This level means that is imperative to carry out an investigation and the introduction of corrective measures must be immediately.

4.1 Corrective Measures and Future Work

The results obtained by EWA and RULA indicate that there is an urgent need to introduce corrective measures foreseeing the postural and movements correction. One of the measures was related to the acquisition of ergonomics chairs with dimensions according to the Portuguese ergonomic design of the seats in order anthropometric data [10] so has to make them satisfactory for 90% of the workers, namely: seat width, seat length, height of the seat (which should be adjustable between heights) and backrest height. These dimensions are shown in Fig. 1.

Another ergonomic measure is associated with the reorganization of the workbenches positioning the materials more frequently used into the workers' reaching area (as demonstrated in the Fig. 2). Additionally, the redesign of workbenches should consider an adequate space for the legs (accordingly to the height referred in Fig. 2).

With the purpose of postural correction, an additional measure proposed is the correction of machine position, between the heights of 66.3 and 29.4 cm (relatively to the seat of the chair as demonstrated by Fig. 3). This measure corrects the vertical amplitude of the tasks performance (between the workers' elbows and shoulders height).

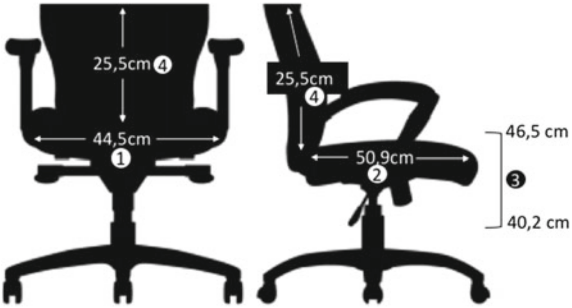
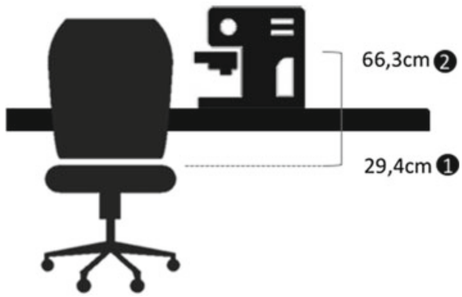


Fig. 1 Dimensions of the chair according to the Portuguese ergonomic design of seats in order anthropometric data: 1. Seat width; 2. Seat length; 3. Height of the seat (adjustable between heights); 4. Backrest height

Fig. 2 Dimensions of the workbench according to the Portuguese ergonomic design of seats in order anthropometric data: 1—within reach (maximum); 2—height

Fig. 3 Height of the crimping machine (relative to the seat of the chair) according to the Portuguese ergonomic design in order anthropometric data: 1—minimum height; 2—maximum height



All these measures were suggested using anthropometric data to redesign the workstation in order to satisfy the variety of physical dimensions as well as human proportions. Anthropometry acquires particular importance in the sense that it determines fundamental aspects associated with the comfort and well-being in the professional activities, in particular those of sedentary nature [11].

Regarding organizational measures, it is essential to train workers to adopt more appropriate postures; to rotate between jobs that do not use the same muscle groups; and allow workers to take more frequent breaks. The definition of these measures was based on EWA results, once some of the most critical topics pointed out by the workers are related to postures and movements, work content and repetitiveness of work.

In addition to these measures, according to the workers' perceptions collected by EWA, a future study is also suggested in order to assess the occupational noise exposure and, consequently, to take into account the proper machines maintenance to eliminating noises caused by badly oiled parts or vibrations. Concerning the risks of occupational accidents, it is suggested special attention to the fact that the employees are operating the machine without the machine protection activated.

5 Conclusions

According to our results there are some points that has to be improved in this workstation, in order to decrease the risk of WMSDs.

The EWA results showed that the most negative scores, according to both analyst and the worker, are postures and movements, content of work, repetitiveness of work, and the thermal environment. The worker also considered "bad" the risk of accidents and noise.

The RULA assessment revel that the critical areas of the body exposed to muscle skeleton risk factors are arms, forearms, wrists and trunk, once these are the parts with the highest score. The final score of this assessment show us a score of 7 points, indicating an action level D. This level means that is crucial to carry out an investigation and the introduction of corrective measures must be immediately.

In order to mitigate the problems encountered we suggested two kind of measures: engineering measures and organizational measures.

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Ergonomic Assessment and Workstation Design in a Furniture Manufacturing Industry—A Case Study

Ana Colim, Paula Carneiro, Nélson Costa, Pedro M. Arezes and Nuno Sousa

Abstract Ergonomics plays an important role to improve health, safety and productivity at workplaces. Faced with the increasing incidence of Work-related Musculoskeletal Disorders (WMSD), the manufacturing industries had taken multiple initiatives to redesign their workplaces based on ergonomic criteria. In this context, the current study has been carried out in a frame assembly workstation of a large Portuguese site of furniture manufacturing where most of workers were continuously exposed to WMSD risk factors (e.g. repetitive manual tasks and awkward postures) and suffering from some kind of musculoskeletal complaints. The main objective of the current study was to improve the ergonomic conditions of the referred assembly workstation. Based on anthropometric data of Portuguese adult population, an ergonomic assessment of a workstation redesign was developed. To verify the suitability of the redesign, Rapid Upper Limb Assessment (RULA) for both workstations, existing and modified, was applied. The results showed that the ergonomic interventions are essential to reduce the mismatch between workers and workstations physical conditions, contributing to the postural correction and, consequently, to the WMSD prevention.

Keywords Furniture manufacturing · Frame assembly workstation · Ergonomics · WMSD · RULA · Anthropometry

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1 Introduction

In modern manufacturing industries, the incidence of musculoskeletal problems is frequent, affecting a significant fraction of the workforce. Currently, in European Union the Work-related Musculoskeletal Disorders (WMSD) constitutes the main occupational health problem [11, 17]. In this context, it is important to clarify the WMSD concept. In spite of the multiplicity of definitions, in general the term musculoskeletal disorders (MSD) includes disorders which affect muscles, tendons, nerves, ligaments, joints, cartilage or intervertebral discs [13]. Whereas the WMSD concept includes: (i) MSD in which the work environment and workload contribute significantly to their occurrence, or (ii) MSD that are aggravated by working conditions [9].

Occupational risk factors (such as awkward postures, repetitive tasks, frequent and/or excessive handling loads, thermal environment), along with individual characteristics (e.g. individual limitations or health problems) and social factors (such as family and economic problems, which may interfere with the motivation and attention during the work), contribute to the WMSD development [3].

These disorders are a major cause of occupational absenteeism and decreased productivity. According to statistical data from the European Agency for Safety and Health at Work, in 2010, the WMSD incidence accounted for 59% of all occupational disorders registered in European workers [17]. Through the 5th European Survey on Working Conditions it was found that more than 40% of workers complain of low back pain and/or muscular pain. In Portugal, an epidemiological study showed that the more prevalent WMSD is the low back pain (38.4% relatively to the totality of WMSD registered), followed by others rachialgias, namely cervical pain (19.2% of total WMSD) and dorsal pain (13.9% of total WMSD), with the remaining disorders reported to the upper limbs [11].

In furniture manufacturing industries, a wide variety of manual tasks with considerable physical demands and several WMSD risk factors are presented (e.g. awkward postures, repetitive manual tasks, handling loads) [12]. On the other hand, the scientific literature shows that ergonomic intervention is the best prevention strategy to reduce the WMSD risk [2], meaning that the WMSD risk factors must be assessed at workstations. According to Takala et al. [16], observational methods (e.g. Rapid Upper Limb assessment—RULA), for assessing exposure to WMSD risk factors, are the most commonly used by practitioners. This kind of methodology is easy to use at the industrial field and provides important results to ergonomic improvements/redesigns [4].

Therefore, the current study resulted from cooperation between an university and a large Portuguese site of furniture manufacturing, which needed to redesign a frame assembly workstation, where most of workers were continuously exposed to WMSD risk factors and suffering from some kind of musculoskeletal complaints.

The present study had the following objectives:

(i) To assess body posture and workstation based on ergonomics aspects;
(ii) To improve the occupational conditions by suggesting a modified workstation, considering anthropometric data;
(iii) To verify effectiveness of the redesign by RULA method.

2 Methodology

The selection of frame assembly workstation was based on internal reports and evidences, which pointed out to the need of ergonomic intervention in this type of workstation. Throughout a careful observation of the work activity, different WMSD risk factors were identified, supporting the workstation selection. This workstation belongs to a section where all the workers are exclusively female gender. In addition, a brief interview to randomly three selected workers was made in order to collect information about work conditions and organization, physical and mental demands, as well as possible musculoskeletal complaints. The relevant dimensions of the workstations were also registered, as well as video-records during the manual tasks performed. Then, the ergonomic assessment included the following phases: (i) WMSD risk assessment by RULA [10]; and (ii) analysis of the suitability of workstations dimensions according to the anthropometric data of the Portuguese population [1]. The mentioned ergonomic assessment was performed separately to both existing and modified workstations (as developed by Kushwaha and Kane [7]). Finally, the results were compared and the redesign of the workstation was analyzed.

RULA is an observational method [4] for assessing WMSD risk for the upper limbs, considering also the neck, trunk and lower extremities position during work activity. Its application involves the postures assessment adopted by the worker during tasks performance, as well as the forces exerted, the repetitiveness of movements and external loads (such as handling heavy materials) [10]. In this study, during the real-time and video-records observations, the most frequent postures were identified in order to apply the RULA. For each posture, different joint angles were associated with a joint score according to a predefined range of angles. Joint angles were determined from digital images imported to LiteCAD®, version 2.0.0.48. These joint scores lead to a final RULA score and recommendations. However, the awkward postures during manual tasks performance are often related to incorrect workstations design. For this reason, the current study includes the application of anthropometric data to assess the existing frame assembly workstation and to redesign it. For this purpose, the following methodological steps were applied: (i) identification of the relevant dimensions in the workstation (e.g. work plane height); (ii) identification of the relevant anthropometric dimensions (e.g. elbows height is used as reference in the definition of the manual work planes height); (iii) identification of the criteria to be used, according to ergonomic recommendations [6, 14]; (iv) verification of suitability, comparing the real values of the workstation dimensions with the anthropometric dimensions of the Portuguese working population [1]. In this stage, the anthropometric dimensions of the female population and the satisfaction of 95% of the population were considered. For the dimensions measured in relation to the ground, the increment of 25 mm was considered, corresponding to the correction of footwear.

3 Results and Discussion

The interview with randomly selected workers showed that the workers of frame assembly frequently present musculoskeletal complaints, mainly pain in different body regions, namely: back, wrists and shoulders. As a positive aspect for the WMSD prevention, it is important to highlight the fact that these workers have a daily program of workplace exercises. However, the repetitive manual tasks and the necessity of awkward postures adoption due to workstation design are risk factors pointed out by the workers.

3.1 WMSD Risk Assessment of the Existing Workstation

From real-time and video-records observation, it was possible verify that the work activity is subdivided into the following manual tasks:

Task 1: Reach materials from a feeding cart (frequently at levels above the shoulders workers);
Task 2: Assembly parts of the frames (in a level above the eyes height of the workers);
Task 3: Reach cubes from a box (lower than work plane, leading to neck and trunk flexion);
Task 4: Apply glue to the cubes (with a glue gun activated by finger pressure);
Task 5: Glue cubes on top of frames (with arms elevation and wrist torsion);
Task 6: Glue cubes/stiles at lower parts of frames;
Task 7: Transfer a set of 3 frames to the pallet (with trunk flexion and torsion).

From each task, the posture more frequent was selected and assessed by RULA.

The scores RULA varied between the action level B (for the task 4, which indicates that an ergonomic intervention could be necessary) and the action level D (for the tasks 1 and 7, indicating that an ergonomic intervention must be done immediately). However, in the tasks 2, 3 and 5 it was found an important WMSD risk level, obtaining RULA scores at the action level C, which mean that an ergonomic intervention must be done briefly at the workstation.

Table 1 Summary of some dimensions' assessment of existing workstation

Measurement point	Recommended criterion	Recommended dimension (cm)	Existing dimension (cm)	Conclusion
Higher level of the frames parts at the feeding cart	Below shoulders height	≤ 120 cm	163 cm	**Very high**, leading to arms and shoulders elevation
Work plane height to the frame assembly	≈10 cm below elbows height	Between 81 cm (for the P_{5^o} of the female workers) and 97 cm (for the P_{95^o} of the female workers)	Between 160 e 90 cm (vertical amplitude)	**Very high**, leading to arms and shoulders elevation, neck extension and wrist torsion to glue cubes in the higher frames parts
Lower level of frames at pallet	Above knees height to avoid excessive trunk flexion	≥ 46 cm	32 cm	**Very lower**, leading to the trunk flexion

The workstation main dimensions that interfere in the awkward postures adoption, as well as the comparison with anthropometric data for the adult Portuguese population are summarized in the Table 1. The recommended values (for the workstation redesign) are aimed at the satisfaction of 95% of the Portuguese female adult population and according to different ergonomic criteria.

This assessment is aligned with a previous study [5], which also identified a higher postural risk for the back and upper limbs in the frame assembly of a furniture industry. In addition, the current results corroborated the workers' perceptions and musculoskeletal complaints registered, justifying the need of an ergonomic intervention. Considering this ergonomic assessment of the existing workstation, a redesign was made with integration of some ergonomic criteria and taking into account anthropometric data of Portuguese population.

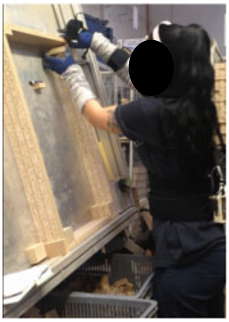
3.2 WMSD Risk Assessment of the Modified Workstation

A prototype for the modified work plane was created, and the main manual tasks were simulated by workers. For this preliminary assessment, the tasks studied were the following:

Task 1: Apply glue to the cubes (with a glue gun)
Task 2: Glue cubes;
Task 3: Glue/assembly stiles during the frames assembly.

Considering the frames dimensions and foreseeing a possible reduction of the awkward postures adoption, it was selected a work plane design in a horizontal

Table 2 Summary of postural comparison between existing and modified workstations

Task	Existing workstation	Modified workstation	Main improvements
Glue cubes	 RULA score = **6**	 RULA score = **3**	It was avoided: (i) Arms and shoulders elevation; (ii) Neck extension; (iii) Wrist torsion (left hand worker in the existing workstation)
Paste/ assembly stiles	 RULA Score= 5 C Action level	 RULA Score = 3 B Action level	It was avoided: (i) Arms and shoulders elevation; (ii) Neck extension

plane (instead in a vertical plane like the existing workstation). The comparison of postural assessment between existing and modified workstations is presented in the Table 2. It should be referred that the task of apply glue to the cubes was not included in this comparison, because it is the same task already assessed at the existing workstation.

Through the RULA results, it can be verified that the postures of the three tasks studied are inserted in action level B. This risk level means that more observation of work activity is advisable and, if necessary, develops an ergonomic intervention. In fact, this assessment was done through a workstation prototype, in which corrections were not yet included (e.g. in the feeding cart, in the glue gun and in the cubes box). The assessment was performed during the simulation of frames' assembly tasks, and the workers were not totally accustomed to the new work method. As future work, it will be necessary to make more observations on this modified workstation after the implementation in the real context of work, and a reassessment of it should be developed.

Comparing both workstations, according to the RULA results, there are improvements in the postural correction, eliminating the arms and shoulders elevation, neck extension and excessive wrist torsion (as mentioned in Table 2). It should be noted that the dimensions of the new work plane seem to improve postural correction during the frames assembly. However, the prototype considered a fixed height (92 cm) and this may not be adequate for some workers, so the modified workstation should consider the adjustable height possibility, in order to accommodate the human variability.

Regarding the task of applying glue (Fig. 1), similar at the both workstations, the gun is the main factor that influences the WMSD risk level, leading to the arm abduction. As mentioned in Sect. 3.1, the RULA score indicated an action level B, recommending more observations and meaning that an ergonomic intervention could be necessary. It should be noted that the obtained RULA score does not totally reflect the biomechanical overload associated with this task, since this assessment method does not consider the relative position of the fingers and the exact number of the actions repeated. In this case, the frequency of the actions, of pressing the trigger of the glue gun, is very high (1500 times per day work). In manufacturing industries, these risk factors, associated with object properties and hand activity, are often associated with the WMSD occurrence, mainly for the hand [8]. Therefore, it is important to replace this tool in order to reduce the overhead in the hand-wrist system.

However, to study in more detail the level of risk associated to these specific situations, this study should be continued. For this, it is recommended to apply advanced observational methods and/or direct methods (e.g. surface electromyography, Kinect data, kinematic analysis) in order to overcome some limitations of observational methods (as defended by Plantard et al. [15]).

Finally, it should be highlighted the importance of workers involvement in the different stages of this study, during the problems identification, design and assessment of modified workstation. As mentioned above, the workers' perceptions were consistent with the assessment results. Guimarães et al. [5] also developed a study based on participatory ergonomics intervention in a Brazilian furniture company, concluding that the workers' participation was crucial for the success of the ergonomic modifications. In this case, the workers demonstrated an increased

Fig. 1 Posture adopted during dosing glue to the cubes

motivation and satisfaction with the new work design, what was explained by improvements inserted as well as by the teamwork done. For these reasons, it is expected that the future work will be continued with the workers participation, as it was developed in these first stages presented in the current article.

4 Conclusion

Manufacturing furniture is an industrial context with several WMSD risk factors. Ergonomic assessment of existing workstations and subsequent redesign of them would give an important contribution for the WMSD prevention. In the current study, a prototype for a new frame assembly workstation was developed and assessed with RULA. This redesign considered workers' anthropometric data and their participation. The RULA assessment showed that the new layout reduces the postural risk associated with frame assembly, mainly for the upper limbs and shoulders. Additionally, workers' perceptions are in line with the ergonomic assessment and they were involved across the study, highlighting the importance of the ergonomics participatory during workstations redesign.

However, future work is required in order to test the prototype in real work context and with a larger sample of workers. The practices and recommendations presented in the current study would be hopefully helpful to others assessments at the company involved in this case study but also for others companies with similar problems.

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Workload Measures—Recent Trends in the Driving Context

Nélson Costa, Susana Costa, Eduarda Pereira and Pedro M. Arezes

Abstract This work is the follow-up of previous research where the authors postulated the need for the establishment of a standardized methodology for assessing the driver's workload, given its importance in the driving context and the upcoming shift in the driving paradigm, namely the widespread use of conditional autonomous vehicles. Even though the early research devoted to this matter was somewhat scattered, a bottleneck in the scope of the dedicated literature seemed to begin to appear in the latter years. As such, the authors aimed to search for the trends in the use of workload measures within this scope, in a recent timeframe. Indeed, this convergence may unveil eventual best practices resulting from the researchers' effort to cope with this recognized handicap in the decision on the best choice regarding workload measures. The results obtained are believed to be indicative of the best path for the standardisation of the method. A systematic literature review was conducted and it was found that there is a growing tendency to simultaneously apply all three workload measures (subjective, physiological and performance), as means to achieve redundant, comparable and more reliable results. Among the specific measures of workload, the most frequently used subjective measure is the NASA-TLX, whereas the HR-related measures are the most frequently used among the physiological measures and the most frequent performance measure is the primary driving task activity.

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Keywords Cognitive workload · Mental workload · Driving · Human factors · Subjective workload measures · Physiological workload measures · Performance workload measures

1 Introduction

Even though workload is not a new research topic, there has been an increasing interest in its study given, on the one hand, the recognition of the impact of workload (mental, in this case) on the execution of tasks in general and, on the other hand, the impending globalized change of mobility, whose success is strongly linked to the management of the driver's workload [1, 2].

Early in 2009, Coughlin et al. [3] proposed an AwareCar concept, aimed at detecting the driver's workload state of either fatigue, optimal or stress and adapting the Human-Machine Interaction (HMI) in order to improve the driver's situational awareness and, therefore, improving performance and safety. It is now generally recognized the weight of the workload in the safety of driving and, therefore, in the feasibility of new autonomous vehicles. Despite this widespread awareness, and with the full deployment of this new mobility models approaching rapidly, it is interesting to notice that, still, researchers are working to fully grasp the concept of workload and to rigorously, precisely and exactly assess it. Indeed, workload is not only closely related to stress, but also to fatigue, burnout and inattention.

Hancock and Desmond [4], had already realised that trying to define workload would be controversial since, despite the terms stress and workload arose from somewhat different traditions, there was a great deal of conceptual overlap in describing demands on the individual arising from both internal and external factors.

Withal, to what concerns solely to the autonomous driving context, there is a level of autonomy in which this incapability becomes particularly dangerous. This regards such a special situation that, some manufacturers even decided to skip introducing vehicles with this level of autonomy—the level of conditional driving automation, whereby the driver has to be able to resume control of the primary driving task when requested by the vehicle [5]. In other words, in this level of autonomy, the driver may be performing any other secondary task to driving but, in an unsuspicious moment, the vehicle may request to pass the dynamic driving task, forcing the driver to cease the secondary task and resume control of the vehicle. This mandates that the driver never experiences pernicious workload levels such as extreme fatigue or distraction, at the cost of not being able to effectively and safely resume the dynamic driving task.

The importance of workload in this area has not been neglected, much knowledge has been created over time in this area. What has hindered, however, the construction of a global, normalized concept is its inherent complexity. In fact, the comprehension of a concept that concerns the human factor, in all its extension, is not a task that is foreseen easy or expeditious, because it congregates too many variables. It is postulated that several measures may be indicative of mental workload and that these can even relate to each other [1]. Indeed, this scattered pattern in research has made it very hard to reach a unified, concerted workload concept, because it made it really hard to establish a comparison between the results which were being divulged to the scientific community. Therefore, this translates into an obstacle in the development of such workload management systems, as if there is no unified workload concept, whoever is downstream in the investigation has nowhere to base themselves to implement a system that manages the mental workload in a way that is recognizably efficient and that can be validated.

Workload measures can be classified into subjective, physiological and performance. Subjective measures include unidimensional scales (comprising the Modified Cooper-Harper Scale and the Overall Workload Scale) and multidimensional scales (NASA Task Load Index Scale (NASA-TLX), NASA-RTLX and Subjective Workload Assessment Technique (SWAT)) among others. Within the physiological measures, there are the cardiac measures (that include heart rate (HR), heart rate variability (HRV) and blood pressure) which can be obtained via electrocardiogram (ECG), the respiratory measures (that contain the respiratory rate (RR) and volume and concentration of carbon-dioxide in air flow), the eye measures [(including eye blink rate and percentage of closure (PERCLOS)], the skin measures [including galvanic skin resistance (GSR) and skin temperature (ST)], the speech measures and the brain activity measures [e.g., electroencephalogram (EEG) and electro-oculogram (EOG)]. Finally, the performance measures can either be primary task performance or secondary task performance measures [1].

In this work, the authors posit that, given the volume of workload research in the autonomous driving context that has been constructed so far, if there is a specific tendency in the latter researches, these may be a clue to the much needed standardisation of the methodology to assess mental workload in drivers. Hence, the goal of this research was to search for the trends in the use of workload measures within this scope, in a timeframe that was recent, so as to try to unveil eventual best practices resulting from the researchers' effort to cope with this recognized handicap in the decision on the best choice regarding workload measures, which may be indicative of the best path to the standardisation of the method.

2 Methodology

This work is based on a Systematic Literature Review (SLR), which was conducted by the authors in the course of their study on autonomous vehicles (AV). This SLR followed a 3-step approach and tried to answer the research question: "Which workload measures are researchers recently using to assess drivers' workload?".

Three bibliographic databases were selected (ISI Web of Science, Scopus and PubMed) and the keywords "driver workload measurement" were searched among Title, Abstract and Keywords for the time span from 2015 to 2019. Review articles were excluded, because it was important that the authors, themselves, performed the measurements. Among the total 101 documents retrieved by the databases, 68 were accessible, including the resources available via the National Consortium b-on. After duplicates were removed, a total of 48 articles were retrieved from the databases. For the present study only a selection of these articles has been considered. The exclusion criteria are:

- The data collected was regarding other types of workload (e.g., physical workload);
- The data collected was regarding workload that was not directly related to maneuvering a vehicle;
- The data collected intended to assess situation awareness in a manner that would distinctly differentiate it from workload;
- The researchers presented theoretical postulations and/or proposed alternative methods only relying on theory and previous works;
- The papers were not written in English.

This triage resulted in a final total of 24 articles of interest for this study.

3 Results and Discussion

The results obtained from the documents of interest retrieved from the databases and processed through SLR are presented in Table 1.

Figure 1 shows the percentages of the specific subjective measures used.

Without a doubt, the NASA-TLX is the most widely used specific subjective measure. It also should be noted that this percentage does not account for other NASA-TLX-based methodologies, which, by themselves, account for another 10% of the total of the specific subjective measures.

The relative percentages of the specific physiological measures are shown in Fig. 2.

According to Fig. 2, the most resorted to physiological measure is the ECG, which encompasses all the HR-related measures, including HR and HRV in both frequency and temporal domains. The EOG is an alternative methodology to the EEG to measure brain activity and another form of measuring eye blink rate and eye closure interval. Its little expression among the used specific physiological measures may be explained by the fact that it is rather an intrusive measure (Miller, 2001).

From the observation of Fig. 3, where the specific performance measures used are displayed, it is possible to verify that most used is the primary task measure, with DRT, measures of speed and lateral offset having considerable expression, as well as the secondary n-back task, on an individual level (see Table 1 for detailed information about primary, secondary and dual task).

Table 1 SLR results

References	Workload measure	Specific workload measure
Jeong et al. [6]	Subjective	SWAT
	Physiological	ECG
	Physiological	EMG
	Physiological	EOG
	Physiological	GSR
Čegovnik et al. [7]	Physiological	Pupil diameter
	Physiological	Blink rate
	Physiological	Eye movement
	Physiological	Fixation rate
	Performance	Primary task: Detection Response Task (DRT)
	Performance	Secondary task: n-back task
Shakouri et al. [8]	Subjective	NASA-TLX
	Physiological	RMSS
	Physiological	HR LF
	Physiological	HR HF
	Physiological	HR LF/HF ratio
	Performance	SD of speed
	Performance	SD of braking force
	Performance	SD of steering angle
Horrey et al. [9]	Subjective	Modified NASA TLX
	Physiological	NIRS for cerebral hemoglobin oxygenation
	Physiological	Pupil diameter
	Physiological	HR
	Performance	SD of headway distance
	Performance	SD of the lateral offset from road center
	Performance	Variability of speed
	Performance	Primary task: DRT
Makhtar and Itoh [10]	Performance	Secondary task: PASAT (Paced Auditory Serial Addition Test).
	Performance	Secondary task: arithmetic task
Li et al. [11]	Physiological	Pupil diameter
	Physiological	Blink frequency
	Physiological	Average blink duration
	Physiological	Saccade frequency
	Physiological	Average saccade duration
	Physiological	Fixation frequency
	Physiological	Average fixation duration
	Physiological	Dwell time on AOI
Ruscio et al. [12]	Subjective	NASA-TLX
	Physiological	Heart rate
	Physiological	High frequency power of heart rate variability
	Physiological	Blood volume pulse amplitude
	Physiological	Cardiac Autonomic Balance (CAB)

(continued)

Table 1 (continued)

References	Workload measure	Specific workload measure
Hernández et al. [13]	Subjective	NASA-TLX
	Physiological	EEG
	Physiological	EMG
Puspasari et al. [14]	Subjective	KSS
	Physiological	EEG
Heikoop et al. [15]	Subjective	Post-task Dundee Stress State Questionnaire (DSSQ)
	Subjective	NASA-TLX
	Physiological	ECG for heart rate
	Physiological	HR variability time-domain (SDNN)
	Physiological	HR variability frequency-domain (LF/HF ratio)
	Physiological	Eye movement Gaze spread (standard deviation of the gaze coordinates)
	Physiological	Eye movement dwell time (time focused on a particular area of interest [AOI]
	Physiological	Eye movement PERCLOS
	Performance	Secondary task: 2-back task
Heine et al. [16]	Subjective	NASA-TLX
	Physiological	ECG for heart rate variability
	Performance	Primary Task: The Lane Change Task (LCT)
	Performance	Secondary task: n-back task
Solís-Marcos and Kircher [17]	Subjective	NASA-TLX
	physiological	ERP EEG
	Performance	Primary task: Tracking task
	Performance	Secondary task: Auditory oddball task
Darzi et al. [18]	Subjective	NASA-TLX
	Physiological	RR
	Physiological	ST
	Physiological	GSR
	Physiological	ECG
Jizba [19][a]	Subjective	RSME Scale
	Physiological	Eye movements: Total Glance Time
	Physiological	Eye movement: Number of Glances
	Physiological	Eye movement: Mean glance duration
	Physiological	Eye movement: Maximum glance duration
	Physiological	Eye movement: SD of Glance durations
Sugiono et al. [20]	Subjective	NASA-TLX
Balters et al. [21][b]	Physiological	NIRS for scalp activity
Galy et al. [22]	Subjective	NASA-TLX
	Performance	Number of collisions with pedestrians
	Performance	SD of the lateral offset from road center

(continued)

Table 1 (continued)

References	Workload measure	Specific workload measure
Ross et al. [23]	Physiological	ERP from EEG (scalp activity)
	Physiological	Eye movement (horizontal)
	Physiological	Eye movement (vertical)
	Performance	Primary task: orienting task
	Performance	Primary task: continuous driving task
	Performance	Secondary task: memory task
	Performance	Dual task: primary and secondary tasks (orienting while memory)
	Performance	Secondary task: Horizontal electro-oculogram (HEOG) calibration task
Paschalidis et al. [24]	Physiological	Electrodermal Activity (skin conductance)
	Physiological	Heart rate
Wang et al. [25]	Subjective	Subjective evaluation for workload through 5-point likert scale
	Physiological	Pupil diameter
	Performance	Secondary task: accuracy
Solís-Marcos et al. [26]	Subjective	Question "How mentally demanding was the task?" (obtained from the "Mental demand" sub-scale in the NASA-TLX; Hart and Staveland 1988) with a modified scale
	Subjective	KSS
	Physiological	ERPs
	Performance	Secondary task: auditory oddball task
Hu et al. [27]	Physiological	Heart rate variability
	Performance	Speed
Koenig et al. [28]	Physiological	ECG for HR (normally positioned for ground truth)
	Physiological	ECG for HR (automotive grade sensor systems were embedded into a driver seat and a steering wheel)
	Performance	Secondary task: 2-back task
Ma et al. [29]	Subjective	Swedish Occupational Fatigue Inventory (SOFI-C)
	Subjective	Modified KSS
	Physiological	Pupil diameter
	Physiological	Horizontal gaze
	Physiological	Vertical gaze
	Physiological	EEG
	Performance	SD of the lateral offset from road center
	Performance	Mean speed
	Performance	SD of speed
	Performance	Car following distance (headway distance)

[a]The authors did not execute performance measures but acknowledge would be important to further apply them
[b]According to the authors: "(..) we did not apply a secondary measure to test whether variations in cortical activity could be attributed to any changes in the affective dimension, e.g. by means of ECG or GSR."

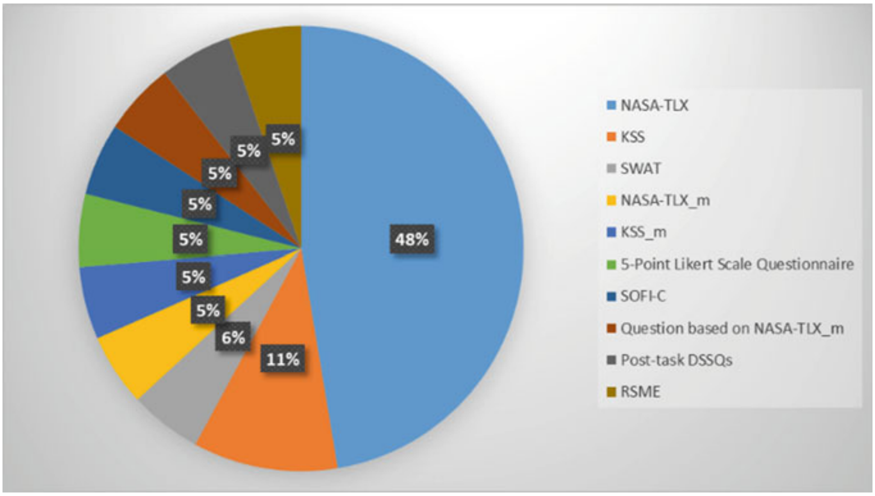

Fig. 1 Percentages of the specific subjective measures used (legend is presented clockwise, starting with NASA-TLX)

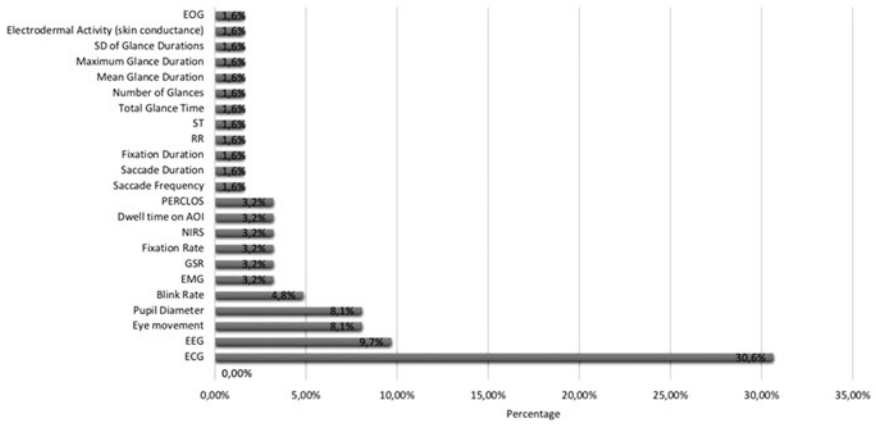

Fig. 2 Percentages of the specific subjective measures used

Figure 4 presents a temporal evolution of the workload measures used, where single use of a workload measure can be seen, as well as different combinations of two workload measures and the use of all 3 types of workload measures.

It can be understood why, in the beginning, research was somewhat scattered along the different available workload measures. It made more sense to, in an initial state, evaluate only small groups of workload evaluation measures, rather than aiming at first, the Herculean task of evaluating the whole set, compounded by the fact that any synergetic or other dependent effects were unknown. Results show that

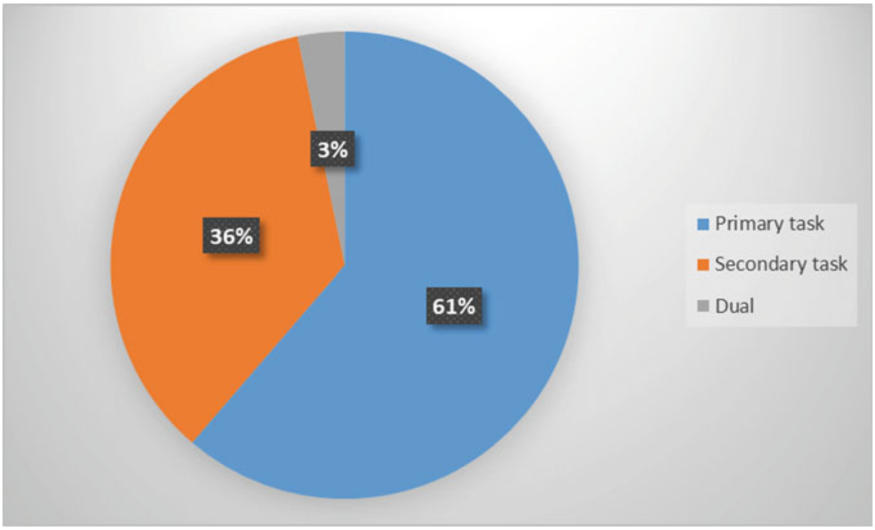

Fig. 3 Percentages of the specific performance measures used

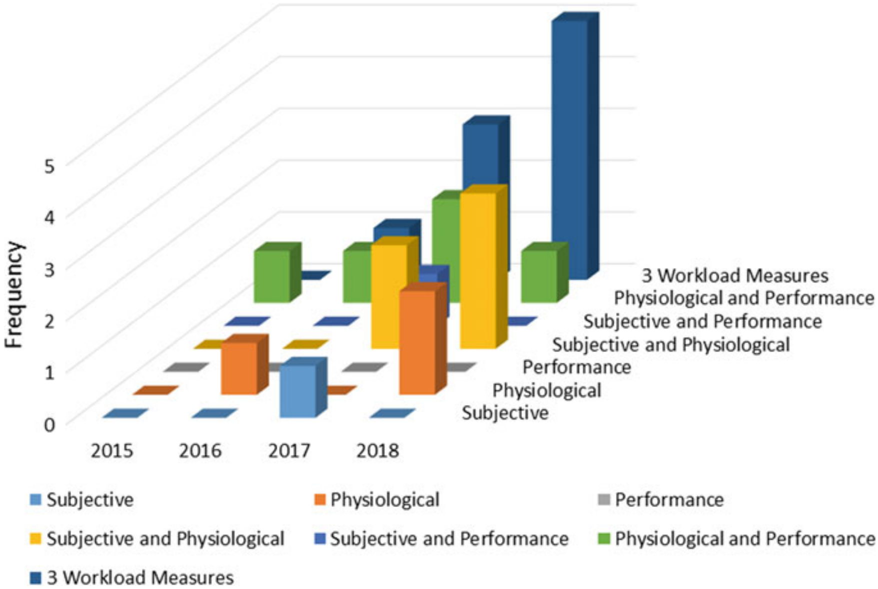

Fig. 4 Use of the different workload measures over the 5-year time-span

not only has the amount of researches devoted to this theme increased greatly, but also that there is an increasing tendency to conjointly use the three types of measures. It seems logical to assume that the use of redundant measures from different sources grants the authors, upon comparison between the results obtained, more confidence that the measures are, indeed, effectively measuring workload, should they correlate with each other as expected. It should be noted that these results, expressive as may be, do not reflect the opinion of, at least the authors of two different papers included in this SLR, who expressed the need and legitimacy of implementing alternative measures to those that they used. Had they had the means to be able to carry out their studies as they understood best, the results would have been even more expressive.

4 Conclusions

For some time now, human factors researchers have acknowledged the need to further study and comprehend the workload concept. The fast evolution that research in this field has undergone, largely motivated by the urgency imputed by the automobile industry, has not been enough to have established, so far, hegemony in the specification of the workload construct. Hence, the authors proposed to seek eventual trends in the use of driver workload measures, in a recent timeframe, in order to shed some light on the presumed best practices that emerged from the researchers' effort to cope with this knowledge hiatus. This work contributes to enlightening the path to the standardisation of the method for assessing drivers' workload. It is concluded that there is a growing tendency to simultaneously apply all three workload measures (subjective, physiological and performance), as means to achieve redundant, comparable and more reliable results. Among the specific measures of workload, the most frequently used subjective measure is the NASA-TLX, whereas the HR-related measures the most frequently used among the physiological measures and the most frequent performance measure is the primary driving task activity.

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Analysis of Acoustic and Luminic Comfort in a Marble and Granite Processing Company in Campina Grande-PB

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Abstract Occupational safety plays a key role in the quality of operations, the health of the worker and the reduction of the accidents. The objective of this work was to analyze the environmental noise and illuminance variables in an industry of the processing of marble and granite. The methodology used was qualitative and quantitative. In the first one, a checklist type data collection instrument was used, based on the conformity requirements of the labor safety regulations used in Brazil. The values of the environmental noise and illuminance variables were measured in the industry. Based on the values found, it was realized that the levels of illuminance are not in accordance with the minimum required by the norm NBR ISO 8995 in all sectors of the industry. In relation to noise, values higher than those allowed by NR 15 were found in some work stations. After the measurements some recommendations were suggested.

Keywords Environmental factors · Working conditions · Safety

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1 Introduction

The marble factory produces pieces of various shapes of rare beauty and great economic importance that are applicable in civil construction. This type of enterprise constitutes the third stage of the industrialization of the mineral granite or marbles, also called processing [1].

The activities carried out in marble works can be considered as an evolution of the works carried out since the beginning of humanity, when man began to use and transform stones for his own benefit, such as the making of spears and other implements for hunting. In spite of the several centuries separating modern men from primitive men, there are still today activities that are developed with probable requirements similar to these two eras of the history of humanity, where workers are often subjected to activities in a few salubrious environments with unfavorable environmental conditions, which could compromise workers' health and safety [1].

Brazil is one of the world's largest producers of granite, both in blocks and finished products. The Northeastern region has a large concentration of granite processing industries, responsible for the commercialization of thousands of tons of pieces processed per year and with strong economic importance in several states (MONTANI 2011).

A major source of stress at work are unfavorable environmental conditions such as excessive heat, noise and low illumination. These factors cause discomfort, increase the risk of accidents and can cause considerable damage to workers' health [2]. According to Silva (2011), work environments where climate, lighting and sound systems are controlled can contribute to the efficiency and effectiveness of the tasks performed in the workplace, as well as it can promote greater comfort to the workers.

The working environment of the mills may expose workers to unfavorable environmental conditions, which could compromise the health and safety of workers and reduce productivity. The application of the principles of Hygiene, Health and Safety at Work in the sectorial industry of marble and granite has fundamental importance to ensure a better use and quality of operations, reconciled, as a priority, with the health of the worker. The objective of this study was to perform an analysis of the environmental, acoustic and luminous factors in an industry of marble and granite processing in Campina Grande - PB, aiming at improving health, safety, comfort, well-being and productivity of workers.

2 Study Environment

The study was carried out in a company with vertical activities in the sector of ornamental rocks located in the state of Paraíba. The main activity of the company is the processing of marble and granite. In Fig. 1, the stages of the marble and granite processing process can be seen.

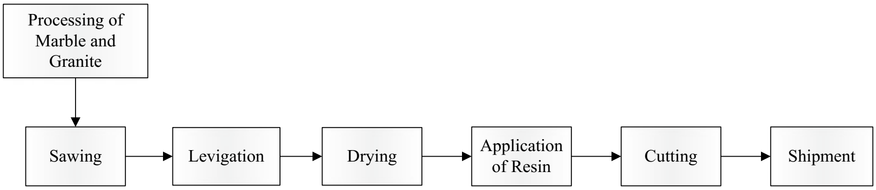

Fig. 1 Marble and granite processing flowchart

Sawing process: The sawing process begins the transformation of the raw material. In this process, the blocks of stone are sawn and transformed into several plates, by means of equipment called looms. The cutting of the block occurs by the combination of abrasive sludge (mixture of grit, lime and water), driven by a set of blades moved by the loom.

Levigation process: After saws on plates, these are washed and sent to a machine called Politica, where each plate is removed by a process of consistency and closing of the plates for a removal of the grooves and the closing of the mineral grains, creating a smooth surface, opaque and more impermeable than a natural face of the same rock.

Drying procedure: After the levigation, the plates must pass 10 min in an oven to remove the humidity present in the plates and proceed to the next step.

Resin process: After removing the moisture from the plates, the application of the resin occurs, which will offer greater strength and durability of the finished product. After the resin has been applied, the plates must be horizontal for 6 h to dry the resin.

Cutting: At this stage, the plates are cut according to customer specifications. At the end of the cut, the plates will pass through the quality control and, if approved, are ready for shipment.

Shipment: In this sector, the pieces are placed in trucks and transported to the final customer.

2.1 Analysis of Environmental Variables

For the analysis of the environmental variables, the main workstations were studied. The measurement points chosen were in the Sawing, Cutting, Levigation, Oven, Resin and shipment sectors. In these environments the noise is intermittent or continuous, being seen its incidence throughout the daily work day. It is also observed from the analysis of the environments, working groups and environmental agents that the dossiers form Homogeneous Exposure Groups (GHE), according to NIOSH or "similar exposure group" according to AIHA. The criterion used to choose these jobs to perform measurements of environmental variables was the worker's exposure to the work routine performed during eight consecutive hours per day, in two four-hour intervals totaling 480 min, thus maximizing the possibility of occurrence of insalubrity. The evaluations were carried out during the five working days of the week, totaling a weekly working day of forty hours, from 7 to 17 h, totaling 480 min of daily exposure to risk, disregarding the two-hour meal interval. The evaluations were carried out under normal working conditions.

2.2 Instruments Used for Measurements of Environmental Variables

For noise and brightness analysis, a thermo-hygro-decibelimeter-portable luxmeter type model THDL-400 manufacturer Instrutherm, shown in Fig. 2, was used.

Noise levels were measured in decibels (dB) with sound pressure level instrument operating in the compensation circuit "A" and slow response circuit (SLOW). The readings were made close to the ear of the worker, as determined by the Regulatory Standard NR-15. In the case of personal use meters, the microphone is positioned over the shoulder, attached to the clothing, within the worker's hearing zone, measured as 150 mm ± 50 mm, measured from the entrance of the auditory canal.

It should be noted that, as also directed to NHO 01, instantaneous reading meters to be used in the assessment of occupational exposure to continuous or intermittent noise should be at least type 2, according to the specifications of ANSI S1.4—1983

Fig. 2 Thermo-hygro-decibelimeter-luxmeter, model THDL-400

and IEC 651, or its future revisions. For continuous or intermittent noise measurement, the meters shall be set to operate in the "A" weighting circuit, slow response circuit and cover a minimum measuring range of 80–115 dB (A).

Before the measurement the equipment must be calibrated and in perfect electromechanical conditions, due to:

- assessing electromechanical integrity and consistency in equipment responses;
- check the charge of the batteries (voltage levels);
- adjust the measurement parameters according to the criteria to be used;
- Perform the calibration according to the manufacturer's instructions.

3 Results and Discussions

Table 1 shows the values of the variables found in each workstation.

Note that, according to NHO 01 criteria, for the purpose of comparison with the exposure limit, it is necessary to determine the Normalized Exposure Level—NEN that is determined by the following expression:

$$\mathrm{NEN} = \mathrm{NE} + 10 \log \mathrm{TE480}\,[\mathrm{dB}] \quad (1)$$

at where:

NE representative mean level of daily occupational exposure;
TE time in minutes of the daily workday (exhibition)

The Normalized Exposure (NEN) corresponds to the Exposure Level (NE) converted to the standard 8 h day shift.

Thus, since the measurements carried out totaled four hundred and eighty minutes (480 min.) Per day, the measured mean value of occupational exposure (NE) is equivalent to the Normalized Exposure Level (NEM) value. Let the logarithm of the above equation be seen to be invalid at the time (TE) equals 480 min of measurement.

In this criterion the daily occupational exposure limit for noise corresponds to NEN equal to 85 dB (A), and the ceiling value for continuous or intermittent noise is 115 dB (A).

Table 1 Survey of environmental variables

Workstation	Noise level (dB)	Illuminance (lx)
Sewing	89.07	112.07
Levigation	77.38	143.85
Drying	77.5	138.48
Application of resin	76.93	127.68
Cutting	87.49	143.54
Shipment	73.8	109.08

3.1 Noise Exposure

The limits of noise tolerance are established by Ordinance No. 3214 of June 8, 1978, of the Ministry of Labor, in NR—15 Annex I, according to Table 2 below:

Regarding the noise, the Regulatory Standard—NR 15 recommends the limit value of 85 dB (A) for a continuous working day of eight hours per day.

In view of the presented data, it is verified that in the sectors of levigation, application of resin, drying and shipment, the levels of tolerance are within the limits allowed by abovementioned norm. However, in sawdust, cut in manual cutter and cut in machine, the found noise levels were high, exceeding the level of 85 dB.

The sector that presents the highest noise produced was the sawing sector, with 89.07 dB (A), which is able to withstand this noise level for 5 h. In the sector of cut, the found noise level was of 87.49 which, according to the norm, allows the maximum exposure of up to 6 h.

Table 2 Tolerance limits for continuous or intermittent noise

Noise level dB (A)	Maximum permissible daily exposure
85	8 h
86	7 h
87	6 h
88	5 h
89	4 h and 30 min
90	4 h
91	3 h and 30 min
92	3 h
93	2 h and 40 min
94	2 h and 15 min
95	2 h
96	1 h and 45 min
98	1 h and 15 min
100	1 h
102	45 min
104	35 min
105	30 min
106	25 min
108	20 min
110	15 min
112	10 min
114	8 min
115	7 min

3.2 Illuminance Analysis

The norm that establishes the ideal average illuminance levels for different activities is NBR ISO 8995-2. The illuminance analysis in each workstation was performed according to this standard, where the following procedures were followed: regarding the class, the class "A" (General illumination for areas used intermittently or with simple visual tasks) was adopted for the sectors of sawing, levigation, application of resin, drying and shipment. In relation to the type of activity, the gross work of machinery was adopted, which minimum, average and maximum values are respectively 200, 300 and 500 lx. In the cutting sector, class "B" (general lighting for work area) was adopted. In relation to the type of activity, the average workload of machinery was used, which presents an average value for illuminance of 750 lx.

The calculations are similar for the level of illuminance in the other areas, differing only in the adopted class.

After the analysis, the levels of illuminance found in all sectors were below the value recommended by the norm NBR ISO 8995-2. These figures demonstrate the inefficiency of the studied company with regard to the variable level of illuminance, a fact that exposes the poor performance of the task, the risks of damage to health and accidents at work.

It is worth noting that during the data collection period there was no interference of artificial lights, only natural light was involved in this process. Therefore, what is perceived through the results obtained is that the company should be responsible for the proper installation of artificial lights in these work environments in order to meet the specific standard.

4 Conclusions

Under the conditions in which this work was conducted and based on the analysis of the results, it can be concluded that the illuminance is the main problem found in the company analyzed since the levels of illumination are below the recommended level. In this way, it is suggested that some measures be taken, such as the installation of artificial lighting sources near the workstations, the increase of windows and lateral openings, the implementation of transparent tiles and a better positioning of machines within the industry.

Regarding the noise levels, values above the recommended level were found in some sectors. This way, it is recommended the use of ear protectors, thus ensuring the comfort, health and safety of workers.

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ErgoVSM on a Hospital Pharmaceutical Stream

Marcelo Pereira da Silva and Fernando Gonçalves Amaral

Abstract Rationalizations often result in impaired ergonomics on the industry. In this context, Lean healthcare is rising as an application and research field and this topic became also relevant to the health sector. This research aims to identify possible solutions that can both reduce process wastes and ergonomics risks at a hospital value stream. The ErgoVSM method was applied at a medium size Brazilian general hospital with approximately 200 beds. In this case, the stream studied was the saline solutions bags flow. Main results indicate that it is possible to control the ergonomics negative impact around lean healthcare if the tools used in the process include human limitations. However, some topics present very specific characteristics and show difficulties on those solutions mainly regarding the work task level.

Keywords Lean healthcare · Ergonomics · Process waste

1 Introduction

1.1 Lean Ergonomics

The human factors play an important role on the development of better production systems. This point of view is shared by different research fields like operation management, ergonomics, sociology and psychology. The essence of this relationship refers to the need of adapt the system characteristics to the worker limitations should be done aiming the work organization [1, 7].

The ergonomics intervention research is wide spread on different industries and it is no rare to see it over a lean systems perspective. These cases often illustrate

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detailed aspects between the two fields and indicate systemic needs for improvements. However the impact of lean strategies on labor demand and occupational health is still unknown on many levels. As the worker is considered the heart of lean model application and allows the achievement of high long-term performance, the topic becomes extremely important for the area. Therefore, it is necessary to investigate in a deeper way the subject to define what good practices are necessary to achieve sustained productivity, quality and safety [3, 5, 6].

It is not solely a principle based relationship that occurs between lean and ergonomics. Topics such as cycle time, production cells and the 7 wastes may have direct and related influence on work pace, job enrichment and workload (poor postures, manual handling and unnecessary dislocation) [2].

1.2 Lean Healthcare Ergonomics

The rationalization of healthcare processes trough lean principles and tools is now a well recognized field of application and research. But the search for higher healthcare system performance can turn into a conflicting factor facing the occupational health paradigm. Several cases report some work intensification related to the reduction of non-value-adding activities. It also can be said that the creation of value at a system level often brings a higher overall physical work load and musculoskeletal disorders (MSD) [4, 10].

Concerning the Lean healthcare area, very little of ergonomic impacts are known in practice. Westgaard and Winkel [12] review indicates that rationalizations often results in impaired ergonomics. Besides, the authors suggest that tools and methods should allow concurrent performance and wellbeing considerations.

Health services have been adopting methodologies to improve processes in an effort to improve their operational efficiency. Lean tools as kaizen and Rapid Improvement Event (RIE) have the tendency to produce small and localized productive gains. But, at least, there are two critical contextual differences between industry and health systems. The first is that consumer and buyer is the same person, and this is necessary to determine the value perceived by the customer that drives the improvements in the processes. The second difference concerns health systems that are designed to be targeted to their capacity, so there is little possibility of influencing demand or fully utilizing their free resources [11]. For example, the porosity concept indicates the need of each system operator to take pauses and rests periods on a working day as a compensation for the reduced cycle times. The physical variation level also puts light on the human limitation that is fundamental for prolonged overall system performance [9].

The leading problem is the ergonomics negative impact of Lean healthcare improvement events. Our hypothesis is that Lean healthcare solutions can control the ergonomics negative impact if the tools used in the process includes human limitations. This research aims to identify possible solutions that can both reduce process wastes and ergonomics risks at a hospital value stream using the ErgoVSM method.

2 Materials and Methods

ErgoVSM is a method developed to consider physical exposure in the analyzed production system trough a participatory approach. The ErgoVSM is based on the regular VSM method and proposes intervention emphasizing ergonomics enhancements in addition to waste reduction. It is suggested as a feasible tool to be used by production engineers and experienced operators for including ergonomics considerations in the rationalization process [7–9].

The ErgoVSM method was applied at a medium size Brazilian general hospital with approximately 200 beds. In this case, the healthcare settings studied were the pharmacy and others related to the elected stream.

A group including four experienced operators (two nurses, one pharmacy assistant and one executive manager) from the selected value stream and the pharmacy supervisor completed the analyses. The lean coordinator along with the ergonomics specialist of the hospital guided the group during the analyses. The ErgoVSM training course was led by the lean coordinator and take 8 h.

The group performed observations and collected data all along the saline bags flow, visiting the hospital sectors to get information from of the purchasers (regarding material quantities and frequencies of delivery) until the waste disposal.

Based on the information the group developed the VSM and the ErgoVSM index. Both were discussed in terms of present and future scenario. Possible solutions aiming the reduce process wastes and ergonomics risks could be analyzed.

3 Results

The ErgoVSM group decided to establish the saline bags stream with more precision regarding the purpose of this analysis. Saline, also known as saline solution, is a mixture of sodium chloride in water and has a number of uses in hospital. It is used in the form of bags with different volumes and technical specificities.

The first part of the stream is very similar on a daily routine. It starts with the pharmacy levels of saline bags and ends with its storage. But the second part of the flow varies because of different sectors demands. So the stream chosen for the analysis was the saline bags demanded by the recovery room. All the details can be seen on the Fig. 1.

Pharmacy professionals meet monthly to schedule the purchase of the saline for the next month. This amount of saline is predicted based on last month consumption. After the purchase request the suppliers make two deliveries per week

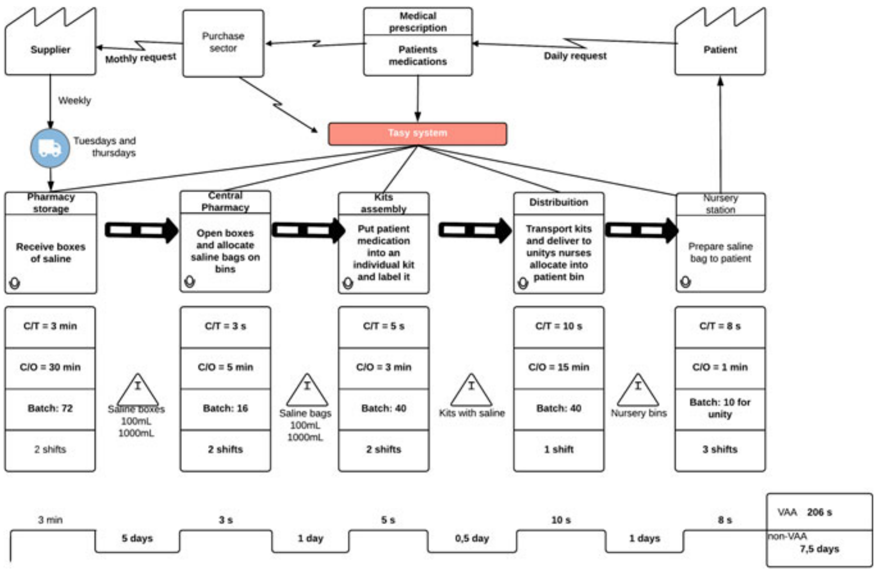

Fig. 1 Value stream map of saline bags created by the ErgoVSM group

(Tuesday and Thursday). The average cost of saline in that hospital is about $14,000 per month.

There are three suppliers for the saline and several dimensions and solutions types. The higher demand relates to 100 and 1000 mL bags. And the lower demands are the glucose saline and 5% saline. On each delivery day about 72 boxes with saline bags are stored. The storage has serious problems with available space for the boxes. The stock turnover takes about one week or less.

Some of the suppliers put the saline boxes right on the store shelves. But most of them just leave at the entrance of the hospital pharmacy. That is an ergonomic issue within the sector because some of these boxes can reach up to 16 kg.

At each day 16:00 h the physicians prescribes on the hospital system all pharmaceutical needed for the patients. With that order the employees physically distributes kits (patient's medications) for all the units on the hospital. One of the most acknowledged wastes come from the delay on some physician's prescriptions, which forces the central pharmacy to attend nurses out of schedule recurrently. There is also stream losses related to saline bags return from the units because of miscalculated requests.

Most of these kits are taken to nursing stations at each level of the building. The stations have individualized bins for the patient's medications. The bins storage also has space difficulties. Some sectors as surgical ward and emergency make 2 or 3 requests for saline each day.

After the map development the ErgoVSM ratings were calculated by the group. Following the method indications all ratings on work task level and value

Table 1 ErgoVSM ratings for each task on the saline bags stream

Task	State	Manual work time (s)	Posture rating	Force rating	Task category
Pharmacy storage	Present	180	8	8	F
	Future	60	4	3	
Central pharmacy	Present	3	2	2	E
	Future	1	2	2	
Kit assembly	Present	5	3	2	D
	Future	5	2	2	
Distribution	Present	10	2	3	C
	Future	7	2	3	
Nursery station	Present	8	3	2	C
	Future	5	2	2	

Table 2 ErgoVSM ratings for the ergonomics on the saline bags stream

Value stream	State	ErgoVSM
Exposure level	Present	7,5
	Future	3,2
Ergonomics potential	Present	6
	Future	5
Porosity	Present	5
	Future	4
Job variation	Present	5
	Future	4

stream level were fulfilled. Considering the present state and the stream characteristics the group has created a visualization of a hypothetical and desirable future. This future was based on the balance between waste reduction and improvements on ergonomics. The data regarding the ErgoVSM can be seen on Tables 1 and 2.

As a suggestion for the hospital, it was indicated that the purchase contract should include that the saline boxes must be delivered on the shelves or in the place project by all suppliers. This action only could reduce postural and force ratings, along whit reduction on manual work time and bring more dynamic to the receipt.

Another possible suggestion includes medication prescriptions by doctors every 6 h rather than 24 h like the current state. The hospital system records the time of receipt of the invoice but not the actual delivery for each box or type of saline solution.

4 Discussion

The ErgoVSM revealed some processes wastes and ergonomics risks along the saline bags stream. Some tasks such the pharmacy storage could reduce processing time, storage time and physical ergonomics risks at the same time with the proposed solutions. Others wastes does not have such combined possibility but still can be reduced and contribute to the stream value. Similar limitations between lean ergonomics solutions are known on the manufacturing industry [5, 6].

The ErgoVSM method has shown good applicability and was feasible to the hospital case and group participation. Beyond the stream value mapping, the method brings specific ergonomics task considerations and allows improvements on a micro and systemic level [7–9]. There are a few published papers that use the method and none of them are directed to hospital context. Therefore more applications are needed to test its relevance on this area.

As already mentioned, work intensification related to non-value-adding activities could be seen in this study [4, 10]. The pharmacy storage, for example, has high levels of posture and force ratings. However it this relationship depends greatly on the task category and ergonomics characteristics. Besides that the results suggests that impaired ergonomics found were not strictly related to the rationalization process [12].

It can be said that the wastes such inventory and over production found on the hospital process not necessarily relates directly to ergonomics risks. But the waste such motion and transport obviously does. And it appears imperative that solutions that can both reduce process wastes and ergonomics risk has to consider the whole stream to become apparent. In other words, the value stream level has more impact possibility than work task level when it comes to improve healthcare systems.

5 Conclusions

The main findings on this study suggest that it is possible to control the ergonomics negative impact around Lean healthcare if the tools used in the process includes human limitations. However some topics present very specific characteristics and show difficulties on those solutions mainly regarding the work task level.

Despite the contribution of our study, further researches are necessary to improve the comprehension around the subject. Therefore, lean healthcare research needs more cases and providing a general overview about the problem is fundamental for hospitals real life problems.

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Reliability of Forearm Skin Thermal Assessment During Handgrip Exercise

Carolina Magalhaes, Pedro Silva, Ricardo Vardasca, Paulo Abreu, Joaquim Mendes and Maria T. Restivo

Abstract Handgrip force test has been used to provide important occupational health indicators about worker's senescence and upper limbs physiological condition. Although, these indicators are mostly based in mechanical assessments, providing maximum force and accumulated work, there is also internal physiological energy spent in handgrip exercising that can be re-motely measured through infrared thermal imaging (IRT). This research aims to assess the reliability of IRT measurements, when performed by different operators. IRT images of 13 participants' forearm were taken during the performance of a gripping test. Three different regions of interest were defined for thermal measurements and analyzed by two recently trained observers. The results were statistically assessed, through student t-test, kappa analysis, Interclass Correlation Coefficient, Bland-Altman limits of agreement and Spearman correlation. It has shown evidence of reliability and data consistency, meaning that the proposed methodology is reproducible for performing regular occupational medicine handgrip assessments in daily practice.

Keywords Forearm skin temperature · Handgrip force · Infrared thermal imaging · Reliability and reproducibility

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1 Introduction

1.1 Handgrip Force (HGF)

The appearance of musculoskeletal disorders is a common sequel of body tissue aging [1]. Over the last decades, this condition has begun to affect younger groups, being work-related tasks appointed as the main cause [2]. Upper limbs extremities are among the most impaired body areas [3, 4] where muscle damage is easily confirmed by handgrip force (HGF) decline [5].

The assessment of HGF is possible through the use of dynamometers, a portable, easy to use and low cost tool [6]. This measuring device is frequently associated with mechanical or aerospace engineering projects to quantify torque, force and power [7, 8]. Lately its potential application range has been explored, with profound studies related to body health condition assessment. Recent use of these instruments is encountered on sport science field studies to assess pedal power of professional cyclers [9] and determine the impact of cold hand temperatures on rock climbers' performance [10]. Different medical specialties have also taken advantage of this tool, using HGF as a predictor for falls on women after hip surgery on orthopaedics [11] and as an indicator of nutritional deficits in dietetic research [12]. In the neurological field ankle stiffness was investigated with the aid of dynamometers and correlated with cerebral palsy and multiple sclerosis [13], while muscle hand strength was evaluated on amyotrophic lateral sclerosis patients [14]. Great advantages can also be retrieved from its implementation on rehabilitation studies, working as a device to monitor progress and treatment efficiency on, e.g., lung transplant recipients [15], post-stroke patients [16] and, more thoroughly, subjects with muscular disorders [17].

Apart from leased muscle tissue, blood circulation is also altered upon muscular mal-function [18]. Thus, the addition of a diagnosis component, representative of this alteration to HGF measurements, could improve confidence on the conclusions attained. Given this, the assessment of HGF was included in routine occupational medicine appointments to identify situations at risk [19, 20].

1.2 Infrared Thermal Imaging (IRT)

Infrared thermal imaging (IRT) is a modality that maps the skin surface temperature distribution in a non-invasive and non-ionizing manner. It is able to detect temperature fluctuations on the skins' surface, caused by blood flow changes, reflecting physiological situations [21, 22].

Despite the successful applications of IRT to medical diagnosis and monitoring on musculoskeletal, vascular, autonomic nervous and locomotor systems [21, 23], thermal measurements are dependent on several elements that can affect the confidence of the final results [24]. Technical aspects involving image analysis and processing stages, e.g., placement and size of regions of interest (ROI), are one of the impacting factors, due to different interpretations among users [25, 26]. Several studies have been performed to assess inter-rater reliability measurements of thermal image analysis on foot [27, 28], upper body [26], upper trapezium [29] and masticatory muscles [30], as well as, full body images [31]. The results show that this parameter can vary among body areas [26, 31, 32], even though excellent values are reached in the majority of works [27, 28, 30]. The evaluation of this parameter on thermal measurements of the forearm is scarce, while needed, to secure the employment of IRT in clinical daily practice.

1.3 HGF and IRT

In order to add more information to the HGF assessment, a research group has developed a methodology to quantify the physiological energy spent in the HGF exercise [33], the same group also developed a tool to automatically analyze the infrared images taken during the HGF exercise and compared the results obtained between manual analysis and those given by the developed software application [34].

It is aim of this research to verify the consistency and reliability of the defined ROIs at the forearm assessment with infrared images when the measurements are made by different observers, demonstrating that the procedure is reproducible in daily occupational medicine practice.

2 Methodology

2.1 Forearm Thermal Images Capture

This research consists on the analysis of the thermal behavior of the forearm skin, when subjected to HGF exercise. A total of 13 healthy participants (9 men and 4 women) with ages of 26 $\pm$ 5 years old, with a 26.0 $\pm$ 4.5% of body mass index, engaged in the test. The examinations started with 10 min' period of thermal acclimatization and resting, followed by a HGF exercise with a total duration of 100 s. During this period, a baseline IRT image was firstly acquired, followed by the performance of 10 consecutive grips of 5 s each, ending with a resting phase were the participant remained holding the handgrip device over a forearm support. An image was taken per second, making 100 IRT images for each participant. The images were recorded by a thermal camera FLIR A325sc (focal plane array sensor size of 320 $\times$ 240, a Noise Equivalent Temperature Difference of <50 mK at 30 °C and a measurement uncertainty of $\pm$2% of overall reading), which was turned on 15 min before the first capture to improve electronics thermal stability.

2.2 Thermal Images Analysis

The images were processed on the FLIR ThermaCAM Researcher Pro 2.10 software package (Fig. 1a) and three ROIs were defined and used to extract per each the mean temperature. The defined ROIs were (Fig. 1b): a circle over the digital flexor muscle (ROI1), a small rectangle over the wrist radial artery (ROI2) and another over the wrist ulnar artery (ROI3).

The size of the ROIs was maintained for all images and the same procedure was followed by the two recently trained observers. Each observer recorded their measurements in a spreadsheet for further analysis.

2.3 Intra-observer Statistical Analysis

The software IBM SPSS v24 was used for the statistical analysis. The student t-test was used to verify the null hypothesis of analysis independence between the two observers. The Kappa analysis was used to measure the adjusted agreement between two raters for a binary outcome. The Interclass Correlation Coefficient (ICC) was calculated to verify the data consistence of each ROI and the agreement correlation per measurement of each observer. Finally, the Bland-Altman limits of agreement were verified to assess reliability and agreement between two measurements. The degree of confidence considered for the statistical tests is of 95%. For comparison proposes, the Spearman correlation was also calculated, but Correlation is not a suitable method for checking reliability, since association and agreement are not the same. Correlation quantifies the tendency for one variable to increase (or decrease) as another increase, by how close points lie to any straight

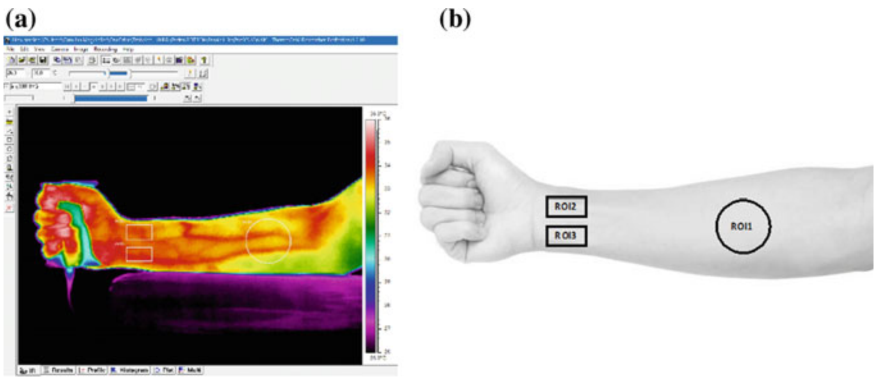

Fig. 1 **a** The thermal images processed in the FLIR ThermaCAM Researcher Pro 2.10 software (left); **b** the ROIs placed at the forearm (right)

line on a scatter plot. Agreement means that repeated results are equal, so points must lie on line of equality.

It is important to bear in mind that a reliable tool is expected to measure in the same way at all times, enforcing consistency, reproducibility and agreement.

3 Results

A total of 1300 thermal images were analyzed by each observer and recorded measurements used for the inter-rater comparison statistical tests.

In the student t-test the null hypothesis is that - there is a difference between the corresponding measurements made by the two observers, statistical evidence of rejecting the null hypothesis was only found for ROI2 ($p = 0.021$) and ROI3 ($p = 0.008$), at the ROI1 ($p = 0.061$) there was no evidence for rejecting the null hypothesis, however the p value is close to the limit.

The Kappa analysis provides the measurement of agreement between the corresponding measurements made by the two observers for the three ROIs (Table 1) and is calculated by finding and standardizing the difference between the observed and expected agreements. It can be verified that the best result belonged to ROI1 and the worst to ROI2.

The Interclass Correlation Coefficient (ICC) test provides the data consistency and ICC of single measure per ROI (Table 2). The closer it is to 1 the best, which was for ROI1 and worst for ROI3.

The Bland-Altman limits of agreement charts (Fig. 2) showed that only 5% of all IR measures between observers are outside the 95% agreement limits, being these agreement limits of ±0.5, ±0.8 and ±2.5 for ROI1, ROI2 and ROI3 correspondingly.

The Spearman correlation between observer measurement was calculated per ROI (Table 3) since the dataset did not followed the Normal distribution (Shapiro-Wilk test), and has shown that the correlation was higher for ROI1 and lower for ROI3.

Table 1 The Kappa measurements of agreement per ROI

ROI	Kappa measurement of agreement	*p* value
ROI1	0.366	0.000
ROI2	0.283	0.000
ROI3	0.295	0.000

Table 2 The data consistency and ICC of single measure per ROI

ROI	Cronbach's alpha	ICC	ICC 95% c.i.
ROI1	0.994	0.988	0.987–0.990
ROI2	0.984	0.968	0.964–0.971
ROI3	0.978	0.957	0.952–0.961

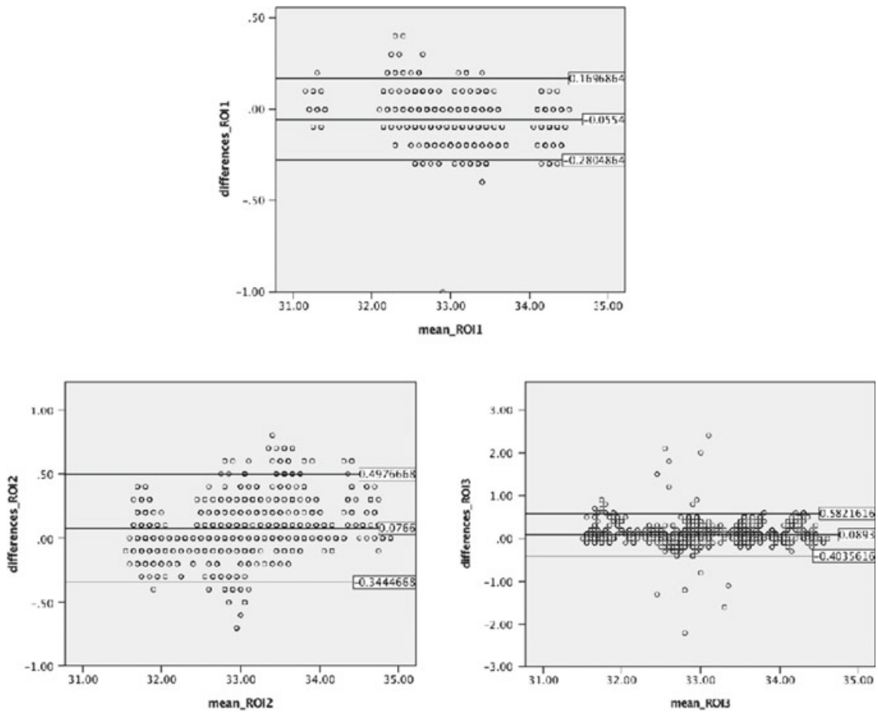

Fig. 2 The Bland-Altman limits of agreement charts for the ROIs

Table 3 The Spearman correlation between observer measurement per ROI

ROI	Spearman correlation (rho)	*p* value
ROI1	0.977	<0.01
ROI2	0.963	<0.01
ROI3	0.951	<0.01

4 Discussion

The obtained results from the statistical analysis of the agreement between measurements made by two recently trained observers showed good reliability, being the agreement greater and the data consistency higher for ROI1, placed over the digital flexor muscle. The obtained results are in line, and outperforming, with those reported by using IRT in dentistry by Costa et al. (ICC = 0.887–0.999) [30] and Dibai-Filho et al. (ICC = 0.615–0.918) [29], in foot by Seixas et al. (ICC = 0.991–0.999; Spearman rho = 0.318–0.462) [27] and Balbinot et al. (Bland-Altman limits of agreement with 95% of measurements inside) [28], in upper body by Rossignoli et al. (ICC = 0.46–0.80) [26] and in full body by Zaproudina et al. (ICC = 0.73–0.99) [32].

In terms of comparison with the previous assessment between an observer and an automated computer analysis [34], the current outperforms it in data consistency and in ICC. These can be explained by the greater ability of human observers of making better and more thoughtful judgments of the correct location of ROIs.

The better results of agreement and consistency encountered for ROI 1 in comparison with ROI 2 and ROI 3 are, somewhat, expected. These latter regions are smaller than the digital flexor muscle one, so slightly different placement of ROIs could result in accentuated differences of measurements between users. Additionally, since wrists are an extremely moveable body area, involuntary movements are more prone to occur during the performance of gripping tests, which could hamper the placement of ROIs and increase the probability of acquiring different thermal measurements for different evaluators.

It is important to mention that this comparison of agreement between observers' measurements is fuller and provides extended results based in more statistical tests than any other used in IRT [26–30, 32, 34].

5 Conclusion

The consistency and reliability of the defined ROIs at the forearm assessment with infrared images presented statistical evidence, meaning that the methodology is reproducible for performing regular occupational medicine handgrip assessments in daily practice. For further research, it is suggested to assess intra-user variability of measurement.

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Correlation Between Manual Lifting of Loads and Low Back Pain in Workers of a Supply Center of Vegetables and Fruits

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Abstract The objective of this study was to investigate the correlation between manual lifting of loads and low back pain in workers at a vegetables and fruit supply center. For that, data were collected on the variables associated with the tasks of lifting loads performed by 49 workers and the characteristics of low back pain. Pain intensity and degree of functional disability were evaluated by Numerical Visual Scale (NVS) and Roland Morris Disability Questionnaire (RMDQ), respectively. The risk of developing low back pain was assessed by the NIOSH Lifting Equation and Static Strength Prediction Program (3DSSPP). The prevalence of low back pain in workers was 73.6%. In the evaluation of the risks associated to the task, it was observed that the workers raised loads with weight above the recommended one, which consequently caused multidirectional static compression

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forces on the L4/L5 and L5/S1 discs of the workers' spine higher than the limits stipulated in literature. In these analyzes, strong correlations were found between work done and self-reported low back pain ($p < 0.001$). In general, it is expected that the risk factors identified in this study will sensitize the managers so that the ergonomic propositions were performed systematically.

Keywords Manual loading lifting · Low back pain · Central supply

1 Introduction

The vegetables and fruits grown in the field go a long way until they reach the table of Brazilian citizens, and the supply centers are present in this process. The supply sector in Brazil handles about 14 million tons of products annually, whose financial collection surpasses $10 billion [1]. The supply centers have the logistic function of economic accomplishment of the food and complementary goods wholesale trade.

Among the various forms of work in the supply centers, it is highlighted the tasks of the load handlers, responsible for loading and unloading the goods from the trucks. However, in many of these centers, it is observed that a large part of the contingent of workers involved in this process does so in a still rudimentary way, using their own body as their main tool.

The manual lifting of loads of different weights, shapes and sizes is characterized by an activity with high energy demand and requires physical force. This activity, when developed in a continuous manner, causes compression forces on the intervertebral discs of the lumbar spine of the workers which contribute to the development of low back pain and deformities in the spine [2–6].

The high incidence of low back pain in workers performing manual tasks has led companies and the scientific community to carry out studies in order to identify the main associated risk factors, in order to implement control measures [7, 8]. In Brazil, although there are no epidemiological studies that investigate the real picture of how workers in supply centers become ill, the pecuniary data provided by the Ministry of Social Security (MPS) estimated that 62% of the cases of leave due to incapacity for work are due to injuries in the spine. The data also revealed that these benefits represented a financial burden of R $117.3 million for both companies and society in general [9].

Therefore, in order to contribute to the treatment of this problem, the present study aimed to investigate the correlation between the manual lifting of loads and low back pain in workers at a vegetables and fruit supply center.

2 Materials and Methods

2.1 Study Design

This transversal study was conducted at a vegetable and fruit supply center located in the state of Sergipe, Brazil. The company was founded in 1973 and has a total area of 34,000 m^2, of which 10 thousand are built, with pavilions subdivided into individual points of sale. The company receives approximately 5000 trucks each month from different Brazilian states and moves more than 60,000 tons of cargo daily.

The sample consisted of 49 workers, all males with a mean age of 34 ± 8 years, mean height of 1.76 ± 0.06 m, mean weight of 77.3 ± 6.1 kg and mean BMI of 25.1 ± 2.2 $kg.m^{-2}$. The average time of services provided by these professionals was of 5.7 ± 2.6 years and average working day of 7.4 ± 1.2 h. No worker claimed to have performed any surgical procedure on the spine, have mobility compromised or have clinical diagnosis of chronic low back pain.

The tasks carried out by these professionals were loading and unloading of merchandise from the trucks, either on fixed platforms installed in the shipping area or with the worker positioned in the ground, due to the unavailability of the platforms (Fig. 1).

2.2 Data Collection Procedures

Data were collected between January and March 2018 and were systematized in three stages (Fig. 2).

The data related to the characteristics of the workers selected for the study were collected in the first stage. In the anthropometric evaluation, the Starrett® metric was used to measure the height of the worker, while the weight was determined by

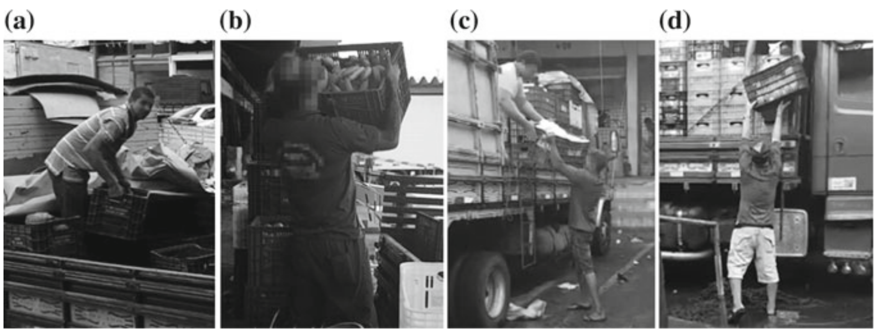

Fig. 1 Process of unloading of goods. **a**, **b** loading and unloading at the platforms; **c**, **d** loading and unloading on ground

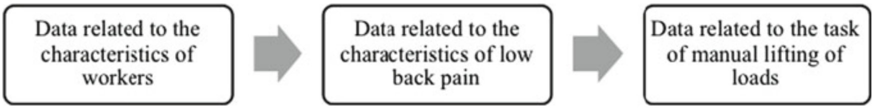

Fig. 2 Methodological steps used in data collection

the Avanutri® digital scale. The measurements were taken with the individual in the orthostatic position and with the head held in the horizontal plane of Frankfurt. The Body Mass Index (BMI) was obtained by calculating the weight division by squared height, and the nutritional status of the workers was categorized according to criteria established by the World Health Organization (WHO).

In the second stage, the characteristics of low back pain self-reported by the workers were raised. The Numerical Visual Scale (NVS) was used to measure the intensity of low back pain by means of a graduated horizontal line from 0 to 10 with the extremes marked as "no pain" and "maximum pain". Thus, each worker spatially located how much pain he was feeling before and after the work process. Values from 0 to 3 were classified as "mild pain", from 4 to 7 as "moderate pain" and above 8 as "severe pain" [10].

The Roland Morris Disability Questionnaire (RMDQ) was used to measure the degree of the worker's functional disability as a result of low back pain. In this evaluation, the researcher performed the reading of 24 sentences describing functional limitations commonly related to low back pain. The responses given by the worker were dichotomous and the result corresponded to the sum of the positive responses. Thus, scores above 14 indicate significant functional disability [11].

In the third step, the task variables were collected, both at the source and at the destination of the lifting. The weight of the load was determined by the Avanutri® digital scale. The variables horizontal distance (H), vertical distance (V) and vertical displacement (D) of the load were measured using the Starrett® metric. The Trident® goniometer was used for measurements the variable load asymmetry (A), while the variable frequency of lifting (F) was determined by the Vollo® digital timer. The quality of the handle (C) was evaluated according to the decision tree established by the National Institute for Occupational Safety and Health (NIOSH). In addition, the systematic observations of the typical postures used by the workers during lifting were carried out, the data being documented and recorded by means of photos and filming.

2.3 Data Analysis

Initially, the NIOSH Lifting Equation was used to determine the Recommended Weight Limit (RWL) for the lifting task, that is, the threshold weight that approximately all healthy workers could support for up to 8 h daily without increasing the risk develop low back pain. From the RWL, the Lifting Index

(LI) was calculated, which provides indexes that indicate the worker's chances of developing low back pain. Thus, when LI values were in the range of 0 to 1, the worker's chance of developing low back pain was minimal, since values between 1.1 and 2.9 increased the risk. A value equal to or greater than 3.0 indicated a high probability of injuries to the spine and the musculoskeletal system of the worker [12].

Next, biomechanical models were constructed in the Three-Dimensional Static Strength Prediction Program (3DSSPP®, version 7.0.4), developed by the University of Michigan, to estimate the static compression forces on the lumbar spine intervertebral discs of workers based on typical work postures. In this process, the anthropometric data, the joint angles, the gripping distances, the weight of the load and the direction of the force applied externally in the hands of the workers in the manual lifting of the load were used.

Finally, the information obtained was stored in a database developed in the Statistical Package for the Social Sciences (SPSS 24) for Windows®, in which statistical analyzes were conducted. The descriptive analysis of the data was used to synthesize and represent the numerical and categorical variables of the study, based on frequency distribution, position and dispersion measurements. In the inferential analysis of the data, the non-parametric Mann-Whitney and Wilcoxon tests were used initially to verify the existence of statistically significant differences between the groups. And then the Pearson correlation coefficient (r) for bivariate analysis of the data. In these tests, were considered the 95% confidence interval and significance level $p < 0.05$.

2.4 Ethical Clearance

This research was approved by the Research Ethics Committee (CEP) of the Federal University of Sergipe Foundation (FUFS), under protocol number 71390817.9.0000.5546.

All the selected workers signed the Free and Informed Consent Term (TCLE) and were instructed on the voluntary nature of the study, the procedures to be adopted in the course of the field research and the use of the information collected.

3 Results and Discussion

3.1 Prevalence of Low Back Pain

The prevalence of low back pain in workers was 73.5; 80.6% of them reported having had at least one episode of low back pain in the last 30 days prior to the interview. In addition, it was verified that no worker looked after medical assistance to treat low back pain, although 47.2% had self-medicated for the control of pain. The remaining 52.8% claimed to tolerate pain without the use of pharmacological drugs or alternative therapies.

Concerning the frequency of low back pain, it was observed that 52.8% of workers claimed to have at least one episode of low back pain during the week, whereas in 30.6% the pains were daily, 11.1% biweekly and 5.6% monthly. It was also observed that in 63.9% of the cases the recovery time was up to three days, and 36.1% of the cases lasted longer. On these occasions, 55.6% of workers said they did not miss work, although only 13.9% reduced their workload due to low back pain.

In the initial evaluation, before the work process, the mean pain intensity reported by workers in NVS was 4.22 ± 0.96 points, with a variation between mild (3) and moderate (6) intensity. In the reevaluation, after finishing the work, the mean intensity obtained was 7.17 ± 1.00 points, and varied between moderate (5) and severe intensity (9). No loader reported absence of pain (0) or extreme pain (10), both in evaluation and reevaluation. There were statistically significant differences between the two measures ($r = 0.85$, $p < 0.01$), as well as a strong statistical correlation between the two measurements ($p < 0.001$).

The mean positive responses for assertive constants in RMDQ were 11.6 ± 3.3 points. No shipper reported absence of disability (0) or severe disability (24 points). The score obtained by 80.6% of the workers was below the threshold of functional disability (14 points). However, 19.4% obtained higher scores and, therefore, were classified as having functional disability due to low back pain. There were statistically significant differences between the scores obtained in the RMDQ of the individuals who reduced the workload due to the low back pain of those who did not ($p < 0.05$). In addition, the existence of a strong statistical correlation between the score obtained in the RMDQ and the following variables was verified: NVS ($r = 0.89$, $p = 0.012$), lumbar pain frequency ($r = 0.85$, $p = 0.015$) ($r = 0.83$, $p = 0.027$) and reduction of the workload ($r = 0.78$, $p = 0.032$).

3.2 Assessment of the Risk of LBP

In the tasks performed on the platforms, the workers lifted, on average, 67 units of loads with average weight of 38.6 ± 7.77 kg and average duration of 44.8 ± 16.95 min. On the other hand, the tasks performed in the ground were, on average, 165 ± 72 units of loads with average weight of 40.9 ± 7.54 kg and average duration of 51.9 ± 11.2 min.

Table 1 shows the mean values of the task variables required to calculate RWL and LI. There were statistically significant differences between the tasks on the ground platforms in the variables H ($p < 0.001$), V ($p < 0.001$), F ($p < 0.01$) and D ($p < 0.01$). There were no significant differences for the variables A ($p = 0.165$), demonstrating that in both situations, the movements performed by the individuals occurred in a similar way.

Table 1 Variables of the manual lifting of loads

	H (cm)	V (cm)	A (°)	D (cm)	F (lev./min)
Platform	36.2 ± 4.6	95.3 ± 23.5	43.7 ± 23.3	47.5 ± 20.2	4.1 ± 1.5
Ground	32.1 ± 4.2	124.8 ± 21.6	98.3 ± 44.5	55.8 ± 21.3	3.3 ± 0.8

NIOSH Lifting Equation indicated that all workers were at risk of developing low back pain. The average RWL for the tasks performed on the platforms was 10.8 ± 1.9 kg and in the ground 10.9 ± 1.8 kg. In relation to the percentage of overweight of the loads, it was observed that the individuals elevated loads with weight 257.4 and 275.2% above the recommended one, respectively. The mean LI for the tasks performed on the platforms was 3.7 ± 1.2 and in the ground 3.9 ± 0.9, as shown in Table 2. These values indicated a high probability of workers injuring the lumbar spine if control measures were not implemented [12].

No significant differences were found between RWL ($p = 0.787$) and LI ($p = 0.612$) for the task performed on the platforms and on the ground. There were significant differences between the RWL and LI of the loaders afflicted by low back pain of those who were not ($p < 0.001$). There was also a strong and positive correlation between the LI and the weight of the elevated loads in the platforms ($r = 0.84$, $p < 0.001$) and in the ground ($r = 0.88$, $p < 0.001$), indicating that the higher was the weight of the load, the greater the risk of developing low back pain. In addition, there were strong correlations between LI and the following variables: NVS ($r = 0.82$, $p < 0.001$), frequency of pain ($r = 0.81$, $p < 0.001$) and recovery time ($r = 0.83$, $p < 0.001$).

The main postures adopted by the workers in carrying out the task of lifting the load were flexion (>40°), extension (>20°) and lateral trunk flexion (>5°). These postures associated with load weight caused multidirectional static compression forces on the workers' spine discs L4/L5 and L5/S1 on the order of 3971 ± 293 N (platform) and 4021 ± 465.8 N (ground) ($p < 0.01$). There was a strong and positive correlation between these forces and the LI ($r = 0.78$, $p < 0.001$), NVS ($r = 0.83$, $p < 0.001$) and RMDQ ($r = 0.79$, $p < 0.001$), indicating that an increase in intradiscal compression contributes to low back pain with stronger and more disabling intensities.

In the mechanism of intradiscal compression, opposing parts of the lumbar spine bone are pressed together by muscular action, weight bearing, gravity, or some external load acting on the length of the bone, and when this force exceeds 3400 N

Table 2 RWL and middle LI

	LC (kg)	HM	VM	DM	FM	AM	CM	RWL	LI
Platform	23	0.77	0.91	0.93	0.83	0.87	1.0	10.8	3.7
Ground	23	0.79	0.85	0.91	0.87	0.89	1.0	10.9	3.9

Note The equation uses several task variables expressed as multipliers (in the equation, M = multiplier) that serve to decrease the load constant (LC) causes micro-trauma, which depending on the degree of evolution, progress to chronic cases [3, 4]. In these cases, the lower the chance of the worker returning with the same physical conditions as before.

Thus, it is recommended to use equipment that provides mechanical assistance for the loading and unloading of goods from trucks, as well as avoiding heavy manual labor. This will reduce health risks to workers as well as minimize damage to the goods, either by improper handling or by adverse weather conditions. The implantation of such equipment was suggested in several studies [7, 13].

In addition, it should be noted that, in the short term or in the absence of the possibility of using automated mechanisms, the work station and the instrumental apparatus necessary for the execution of the work activities should be adapted to the anthropometric measurements of most of the workers. To avoid the use of inappropriate biomechanics, it is advised that when lifting and transporting the goods, it is not recommended to bend the knees, the spine should remain erect and to keep the volume close to the longitudinal axis of the body, avoiding, flexion or medial and axial rotation of the trunk during the process. The decrease in body-load distance has been recommended by several researchers in the area [4-16].

4 Conclusions

In this study, there was a high prevalence of low back pain in workers, revealing the existence of physical overload in the tasks of manual lifting of loads. In fact, the NIOSH Lifting Equation suggested a drastic reduction from 38.6 to 10.9 kg for the elevations performed on the platforms and from 40.9 to 10.8 kg when performed on the ground. The mean LI of 3.7 (platform) 3.9 (ground) corroborates the pain symptomatology reported by the individuals, since the ideal value is below 1.0.

Not surprisingly, intradiscal compression exceeded the limits of the literature. It was observed that the workers experienced compression forces 18.3% (platform) and 16.8% (ground) above the threshold of lumbar spine injuries. Thus, it can be observed that the elevations performed, both on the platforms and on the ground, may have compromised the structure of the lumbar spine of the workers, especially when the movements were performed with the load away from the longitudinal axis of the body and above the level of the shoulders. Strong statistical correlations corroborate these conditions.

From the theoretical point of view, the study made it possible to fill the existing gap in the literature regarding studies of the working conditions of workers in supply centers in the Brazilian context. From a practical point of view, the main risk factors of low back pain in the tasks performed by these professionals were investigated and pointed out the need for a more rigid inspection by the government institutions and that ergonomic solutions should be implemented immediately.

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Prevalence of Musculoskeletal Symptoms in Blue-Collar Workers: Association with Gender and Physical Activity Level

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Abstract This study aimed to investigate the prevalence of musculoskeletal symptoms and the association between physical activity and gender, and the prevalence of musculoskeletal symptoms in different body regions among blue-collar workers working in a Portuguese manufacturing company. The sample comprised 136 blue collar workers. Musculoskeletal pain and related symptoms were assessed with the Nordic Questionnaire of Osteoarticular Symptoms, and physical activity was assessed with IPAQ—Short Version. The association between musculoskeletal symptoms and physical activity and gender was analyzed with the Chi-Square test. Results revealed that the 4 most prevalent body regions where the workers reported musculoskeletal symptoms were: the lumbar region (56.6%), the wrist/hand (50%), the shoulder (45.6%) and the neck (44.9%). No significant association was found between physical activity levels ($p > 0.05$) and prevalence of musculoskeletal symptoms. Women reported a significant higher prevalence of musculoskeletal symptoms in the neck than men ($p = 0.025$). To conclude, blue-collar workers have a high prevalence of musculoskeletal symptoms and the level of physical activity seems not to influence the prevalence of musculoskeletal symptoms in the blue-collar workers of this sample. Gender differences were found

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only in the neck region. The present results emphasize the need of worksite interventions to prevent musculoskeletal pain and related symptoms in this population.

Keywords Musculoskeletal symptoms · Physical activity level · Gender · Blue-collar workers

1 Introduction

The division of labor in sectors that emerged from the Industrial Revolution forced workers to perform tasks repetitively during their work hours or to stay for long periods in the same posture, which causes pain, physical discomfort and musculoskeletal disorders (MSDs) [1, 2]. MSDs are injuries or dysfunctions affecting muscles, bones, nerves, tendons, ligaments, joints, cartilages and spinal discs [3, 4].

According to the World Health Organization (WHO), injuries related to work has multifactorial causes or risk factors, such as: ergonomics, work organization, workplace environment, and physical, psychological and social changes [5]. Workplace health promotion (WHP) initiatives are programs that aim to promote health by reducing its risks and actively prevent the beginning of disease [6] by decreasing stress, excess of body weight, improving nutrition and increasing physical activity and fitness levels. Reviews of the effectiveness of these interventions have shown mainly positive results [7]. Indeed, in the last 20 years, the number of WHP programs in workplace settings has been growing, as their advantages for employees and companies are increasingly being recognized, as they help to reduce employee's health care costs and disability and improve employee's productivity [8].

Physical activity and multidisciplinary interventions seem to have a positive effect on sick leave, costs, prevention of new episodes of pain and physical discomfort, and consequently MSDs [9–11]. Therefore, physical activity interventions to reduce weight, improve physical capacity, improve postural control and reduce musculoskeletal pain among workers are needed to prevent MSD in workers [12–15].

Gender's influence on the prevalence of MSD has also been investigated by previous studies in which is reported significant differences between male and female workers, with females presenting a significantly higher prevalence of symptoms in the neck, shoulders, wrist/hands, upper back and hips/thighs regions when compared to males [16].

The aim of this study was to investigate the prevalence of musculoskeletal symptoms and the association between physical activity and gender, and the prevalence of musculoskeletal symptoms in different body regions among blue-collar workers working in a Portuguese manufacturing company.

2 Materials and Methods

2.1 Study Design and Sample

This observational and cross-sectional study was approved by the ethical committee of local University and by the board of the company. The study was conducted in a multinational manufacturing company with offices in Portugal. The total number of employees in the company is around 1000, however, only 220 were allowed by the administration board to participate. These employees perform prolonged (7 h and 30 min shifts) repetitive moderate force demanding tasks using mainly the upper limbs, while in the standing position. During the execution of the tasks they must handle heavy objects, use screwdrivers and place washers in equipment such as water heaters.

All the participants were full-time workers (40 h/week) and had been employed in the company for at least 6 months. From the 220 employees invited, 209 agreed to participate (87 men; 122 women) with 136 of them being considered blue-collar workers (40 men; 96 women), which represent the sample for the present study. The workers were 37.4 ± 8.5 years old and the mean BMI was 27.3 ± 4.9 kg/m^2, representing, according to the WHO [17], an overweight sample. All participants expressed their consent to participate in the study signing an informed consent form.

Height (m) was measured with the participants standing upright against a stadiometer in bare or stocking feet (Holtain Ltd., Crymmych, Pembrokeshire, UK). Weight (kg) was measured using a portable electronic weight scale (Tanita Inner Scan BC 532, Tokyo, Japan). BMI was calculated from the ratio between body weight and body height (kg/m^2).

2.2 Physical Activity

Physical activity was assessed using the short version of the International Physical Activity Questionnaire (IPAQ) [16]. According to the Guidelines for the data processing and analysis of the IPAQ, total physical activity was expressed as metabolic equivalent (MET) minutes/week by weighting the reported minutes per week in each activity category by the metabolic equivalent specific to each activity (Total Physical Activity = 3.3 MET × walking minutes × walking days + 4.0 MET × moderate-intensity activity minutes × moderate days + 8.0 MET × vigorous-intensity activity minutes × vigorous-intensity days). Physical activity level of the participants was expressed as active, insufficiently active and inactive.

2.3 Musculoskeletal Disorders and Related Symptoms

Musculoskeletal pain and related symptoms were assessed by the Standardized Nordic Questionnaires for the Analysis of Musculoskeletal Symptoms (NMQ) [18], supplemented with questions about localized pain intensity. This questionnaire has been validated to the Portuguese population [19]. The NMQ consists of 27 binary choice questions (yes or no). The questionnaire has three questions correlating to nine anatomic regions (neck, shoulders, wrists/hands, lumbar region, dorsal region, hips/thighs, knees, and ankles/feet). The first is "had some troubles or pain in the last 12 months," the second is "in the last 12 months felt some limitation caused by work in the daily activities," and the third is "had some troubles or pain in the last 7 days" [18]. The pain intensity in the "last 7 days" includes the numeric pain scale (scale 0–10).

2.4 Statistical Analysis

The data was analyzed for statistical significance by using the Statistical Package for the Social Sciences (SPSS v. 25.0) software for Windows. Descriptive characteristics of the participants (age, BMI) were presented as means ± standard deviation. The prevalence of musculoskeletal disorders during the last 12 months, in each body region, was described in percentage (%). The Chi-Square test was used to assess the association between prevalence of musculoskeletal symptoms and physical activity levels and gender. A p value under 0.05 was denoted as significant.

3 Results

The analysis of the NMQ data demonstrated that the prevalence of musculoskeletal symptoms is high, especially in the lumbar region (56.6%), the wrist/hand (50%), the shoulder (45.6%) and the neck (44.9%). In the other body regions, the prevalence was 30.1% in the ankle/feet, 22.8% in the knee and 19.1% in the elbow and thigh/hip regions.

No significant associations were found between physical activity levels and the prevalence of musculoskeletal symptoms but a significant association between gender and the prevalence of symptoms in the neck was found ($p = 0.025$) (Tables 1 and 2).

Table 1 Comparison of musculoskeletal symptoms between physical activity (PA) levels

Body regions	PA active	PA inactive	PA insufficiently active	Chi-square test
Shoulder (n = 62)	51 (49.0)	5 (26.3)	6 (46.2)	$\chi^2(2) = 3.346$; $p = 0.188$
Elbow (n = 26)	19 (18.3)	4 (21.1)	3(23.1)	$\chi^2(2) = 0.226$; $p = 0.893$
Wrist/hand (n = 68)	53 (51.0)	7 (36.8)	8(61.5)	$\chi^2(2) = 2.047$; $p = 0.359$
Thigh/hip (n = 26)	22 (21.2)	4 (21.1)	0 (0)	$\chi^2(2) = 3.398$; $p = 0.183$
Knee (n = 31)	26 (25.0)	4 (21.1)	1(7.7)	$\chi^2(2) = 2.005$; $p = 0.367$
Ankle/feet (n = 41)	30 (28.8)	5 (26.3)	6 (46.2)	$\chi2(2) = 1.798$; $p = 0.407$
Neck (n = 61)	45 (43.3)	9 (47.4)	7 (53.8)	$\chi^2(2) = 0.579$; $p = 0.749$
Dorsal region (n = 19)	17 (16.3)	1 (5.3)	1 (7.7)	$\chi^2(2) = 2.113$; $p = 0.348$
Lumbar region (n = 77)	61 (59.2)	7 (36.8)	9 (69.2)	$\chi^2(2) = 4.152$; $p = 0.125$

Table 2 Comparison of musculoskeletal symptoms between gender

Body regions	Male (n = 40)	Female (n = 96)	Chi-square test
Shoulder (n = 62)	16 (40.0)	46 (47.9)	$\chi^2(1) = 0.713$; $p = 0.398$
Elbow (n = 26)	4 (10.0)	22 (22.9)	$\chi^2(1) = 3.047$; $p = 0.081$
Wrist/hand (n = 68)	16 (40.0)	52 (54.2)	$\chi^2(1) = 2.267$; $p = 0.132$
Thigh/hip (n = 26)	6 (15.0)	20 (20.8)	$\chi^2(1) = 0.621$; $p = 0.431$
Knee (n = 31)	10 (25.0)	21 (21.9)	$\chi^2(1) = 0.157$; $p = 0.692$
Ankle/feet (n = 41)	13 (32.5)	28 (29.2)	$\chi^2(1) = 0.149$; $p = 0.700$
Neck (n = 61)	12 (30.0)	49 (51.0)	$\chi^2(1) = 5.054$; $p = 0.025$*
Dorsal region (n = 19)	5 (12.5)	14 (14.6)	$\chi^2(1) = 0.102$; $p = 0.749$
Lumbar region (n = 77)	20 (51.3)	57 (59.4)	$\chi^2(1) = 0.741$; $p = 0.389$

*$p < 0.05$

4 Discussion

This study investigated the prevalence of musculoskeletal symptoms in different body regions and the association between physical activity and gender, and the prevalence of musculoskeletal symptoms in blue-collar workers of a Portuguese manufacturing company.

When physical work demands exceed the safety margin of the individual physical capacities, this environment increases the risk of physical deterioration and is revealed as musculoskeletal disorders, poor work ability and sickness absence [20].

The results of the present study revealed that the prevalence of musculoskeletal symptoms is high in blue-collar workers especially in the lumbar region (56.6%), in the wrist/hand (50%), the shoulder (45.6%) and the neck (44.9%). In the other body regions, the prevalence was 30.1% in the ankle/feet, 22.8% in the knee and 19.1% in the elbow and thigh/hip regions. The lumbar region seems to be the body region where the highest prevalence of pain in blue-collar workers is reported, which is in line with previous literature [21, 22]. Previous studies reported a prevalence of 54% [21] and 58% [22], which is very close to the percentages reported here. Regions such as the neck and the shoulders are also pointed out as the most prevalent sites of musculoskeletal symptoms, registering in previous investigations a prevalence of 43% and 42%, respectively, which is also in line with the results presented in this paper [21].

In this study, no significant association was found between physical activity levels and the prevalence of musculoskeletal symptoms in any of the assessed body regions. These results are not in line with other studies that observed a significant positive effect of high levels of physical activity on musculoskeletal pain or discomfort in employees [23, 24]. However, it should be noted that the present investigation was conducted in blue-collar workers, who report higher physical demands and less sitting time [25]. Thus, the classification of an employee as physically active at this particular population, can be influenced by their labor activity, and not as the time they spend doing actually leisure time physical activity. This can explain the difference between the results presented here and the results of previous investigations, as they only quantify the leisure time physical activity of the assessed workers [23]. This assumption is confirmed by previous studies conducted in blue-collar workers, where it was quantified the actual time they spent in occupational and leisure time physical activity, being demonstrated that this population spends higher periods of time walking, for example, and less time sitting during the work day than in the leisure time [26].

Overall, the present study found higher prevalence of symptoms in the nine assessed body regions in females. Nevertheless, a significant association between gender and pain symptoms was only found in the neck. Previous investigations have also reported significant differences between male and female gender, with most of them similarly recording higher prevalence of neck symptoms in females, as the results of this paper did [21, 27]. However, these authors also report significant association between gender and pain symptoms in other body regions, such as the shoulders, the wrists/hands, the upper back and the hips/thighs, with women also reporting higher prevalence of symptoms [21].

Work tasks that include twisting movements of the trunk, working with the trunk flexed forward or the hands above shoulder level are reported to be important work-related risk factors. Musculoskeletal pain of a working-age population has many risk factors of which age, high body mass index, stress and work-related physical loading seem to play an important role [28, 29]. Due to high morbidity rates, the importance of preventive measures must be emphasized. When studying the associations between physical exercise and musculoskeletal pain among the working-age population, researchers should pay attention to the factors which are strongly related to pain, such as stress and work-related physical loading [28, 30]. More research with prospective design is needed in order to achieve more reliable information about the true effects of physical exercise on musculoskeletal health.

A limitation of this study is that the sample, although not small, may have not been large enough to reveal significant associations between the explored variables. Moreover, the assessment of physical activity levels was done using an instrument that does not differentiate the physical activity performed in the leisure context from the physical activity in a work context.

5 Conclusion

The population of the study (i.e., employees in job groups with high physical demands) is well documented to have a high risk for physical deterioration as the prevalence of musculoskeletal symptoms is high. In the present sample, the level of physical activity seems not to be associated with the prevalence of musculoskeletal symptoms. In consideration to gender analysis, gender is only associated with neck musculoskeletal symptoms.

If proven effective, specific interventions to different job groups can provide meaningful scientifically based information for the development of public health policies and health promotion strategies for employees at high risk for physical deterioration. This knowledge can be beneficial for occupational health professionals, companies, and employees in these job groups. Future studies should focus on an epidemiological perspective regarding both musculoskeletal symptoms and physical exercise, concerning the relevance of these factors in a global perspective.

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The Influence of Active Workstations on Work Performance, Productivity Indicators and Sedentary Time: A Systematic Review

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Abstract The most of strategies to promote physical activity in workplaces interfere with work tasks and many organizations declined these programs. The aim of this review is to understand the impact of the active workstations on the performance and productivity indicators, and also on the reduction of the sedentary time. This review applied PRISMA methodology. 389 studies were identified by searching the different databases and 12 studies were selected, fulfilling the screening and eligibility criteria. The implementation of active workstations did not have a significant impact in terms of performance and productivity. However, some of indicators revealed some positive changes, namely at sit-standing, walking and cycling conditions. All active interventions had positive effects on the reduction of sedentary work time. However, it is essential that active interventions have promising effects for employers accept the challenge.

Keywords Active workstations · Work performance · Sedentary workplace · Physical activity

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1 Introduction

The entry into a new century brought with a considerable change in the workforce, with a decrease in the number of physically demanding jobs and an increase of about 13% in the services sector [17]. With the advancement of technologies, there has been an increase of the workstations equipped with a display and in a sitting position, resulting in a reduction of the energy expenditure by the workers and influencing the culture of the workplaces [19]. These workers can spend up to 10–11 h per working day in a static sitting posture [30], which represents an ergonomic risk factor [14], being possible to associate prolonged seating time with an inadequate metabolic health, an higher risk of chronic diseases and premature mortality [7, 10, 12]. A wide variety of diseases, from psychiatric disorders such as depression, cancer, cardiovascular, metabolic, pulmonary and musculoskeletal diseases, can be treated or improved through exercise [29].

According to Sjøgaard et al. [29], the workplace is "suggested as a specially prioritized arena for health promotion" and many organizations choose to adopt policies and programs that promote health in the workplace including physical activity, nutrition and mental health, with the aim of reducing health costs, increasing productivity, and reduce absenteeism [8, 25]. Some strategies to promote physical activity at work, such active workstations, are being designed over the years and could be applied in sedentary tasks. Depending on the characteristics of the tasks/workplace, different types of active workstations can be implemented such as: walking on a treadmill, pedaling a bicycle, standing in front of a table with height adjustment or alternating between sitting and standing position [32]. In fact, many studies evaluate the effects of workplace interventions to reduce sitting time at work with different strategies like physical workplace changes, policy changes, information and counselling and interventions from multiple categories [23].

Despite all the advantages of active workstations implementation, it is necessary to attend to their impact on performance and productivity. Although these seem to be effective in reducing sedentary time, there are still few studies about their impact on performance and productivity variables [27]. Consequently, it is imperative to recognize the differences between the concepts of performance and productivity as well as the relationship between the two. The term performance is often related to the term productivity [31], being defined as the efficiency with which individuals perform their tasks, essential to their work [15]. The term productivity is defined as the quality or the state of producing a large result or yielding abundantly, which is often determined by the ratio of output to input [31]. Thus, it is necessary to recognize which performance and productivity indicators are best and which are the best strategies for evaluating results of the interventions, so that they can be as rigorous as possible and implemented based on appropriate criteria and indicators, once the activities vary greatly depending on the requirements of the job [20].

The aim of this systematic review was to understand the impact of the active workstations on the performance and productivity indicators and also on the reduction of sedentary work time.

2 Methodology

The systematic review was carried out using three electronic databases, namely PubMed, Web of Science and Science Direct. The search terms used were "active workstation" or "active work" combined with other terms such as "work performance", "sedentary workplace" and "physical activity. It was possible to fulfill the established methodology, ensuring its compliance and coherence with the research that was already carried out. The PRISMA four-phased flow diagram was used in summarizing the study selection processes [21]. All original articles with experimental designs (clinical trials, randomized trials or others) or observational studies (case-control studies, cohort studies, before-after studies or others) involving only healthy individuals without any associated pathologies were included.

3 Results and Discussion

Initially, 389 studies were identified by searching the different databases, which later resulted in 337 after duplicate removal. Following the PRISMA flow diagram [21] used to help improving the reporting of the present systematic review, 42 studies were then selected according to the application of pre-defined screening criteria, resulting in 35 studies selected according to the application of pre-defined eligibility criteria. In the end, there were included 12 studies [1, 4–6, 13, 16, 22–24, 26, 33, 34], which presented all the characteristics imposed, excluding those who did not comply with the defined conditions. Studies using different designs and methods included different types of interventions regarding active workstations, namely active sitting, sit-standing, walking, elliptical and cycling. Most of them considered sitting and standing conditions as control situations or comparison groups, while others did not consider any control or comparison group. These studies assessed performance, productivity and reduction of sedentary work.

For performance, the most used indicators were cognitive performance, involving typing, reading, correcting, telephone, mouse and computer-based tasks, and to subjective measures, namely attention, participation, focus, motivation, morale and engagement. To evaluate productivity, the most used indicators were to work-related perceptions, attendance/presenteeism, amount and quality of work accomplished, frequency of errors, attention, motivation, relationship with colleagues and mental well-being. On the other hand, to evaluate the reduction of sedentary work, some studies used indicators as time sitting, heart rate monitoring and calculation of energy expenditure.

The outcomes related to workplace performance revealed mostly non-significant effects for the observed indicators. However, there were some positively significant effects on sit-standing conditions (decreased restlessness and increased attention) and cycling conditions (increased positive affect exertion, morale and motivation). There were also some negatively significant effects on walking conditions (decreased cognitive performance namely typing task, mouse task and motor skills), cycling conditions (decreased cognitive performance namely cognitive ability and reaction time), and elliptical conditions (decreased mouse task).

Regarding productivity, the outcomes revealed mostly non-significant effects for the observed indicators. There were some positively significant effects on sit-standing conditions (increased work-related perceptions), walking conditions (decreased percentage of work productivity loss, problems interacting with others on the job and limitations in meeting demands for quantity, quality and timeliness of completed work, and increased cognitive tasks namely processing of sensory information, ability to perform job tasks that involve bodily strength, movement, endurance, coordination and flexibility, and presenteeism), and cycling conditions (increased positive perception, continuity, motivation, energy levels and relationship with colleagues). There were no negatively significant effects observed on any conditions.

Although the effects of physical activity on worker performance are still not very precise, as no association between self-reported physical fitness and work performance has yet been found [3], a study developed by Field et al. [9], found that work performance and mood—self-reported by workers—were higher on days when they exercised in the company gym than on days when they did not. Despite of the numerous health benefits related to the change of workplace behaviors through the implementation of active workstations, workers and employers are likely to reject them if they are an obstacle to productivity or to workers' comfort levels. The introduction of an active workstation in a work environment should address a number of practical concerns in order to achieve the desired levels of acceptance. Besides that, the organizations' values related to the health and productivity are also important factors that influence behavior in the workplace [11].

Finally, for the reduction of sedentary working time, the outcomes revealed positive significant effects on all active conditions, namely active sitting conditions (decreased sedentary time work hours, and increased light physical activity work hours and breaks rates in sedentary time), sit-standing conditions (decreased time sitting and standing at work), walking conditions (decreased sedentary time and increased light intensity and moderate-to-vigorous physical activity, support for being physically active in the workplace, heart rate monitoring and calculation of energy expenditure, and breaks rates in sedentary time), elliptical conditions (increased heart rate monitoring and energy expenditure, and physical activity), and cycling conditions (increased heart rate monitoring and calculation of energy expenditure, and oxygen consumption). Considering that workers spend a substantial part of their day in workplaces, this is an ideal scenario of intervention to decrease and/or end the relationship between work activity and sedentary time. Sallis et al. [28] indicated that to investigate the relationship between health and the workplace, it was necessary to identify individual, social, organizational and environmental factors that can influence the adopted behaviors. The main behavior determinants in the workplace included individual's beliefs and values as well as the organizational culture of the workplace [2, 18].

4 Conclusions

The present systematic review allowed to conclude that the effects of the implementation of active workstations in work environments did not have a significant impact in terms of performance and productivity. In addition, the positive effects of this type of intervention on reducing sedentary working time are noteworthy. The active interventions should ensure promising effects, as change habits and improve workers well-being, for motivate employers to implement it. In this study, any article included investigate the industrial environment and few considered the workers' perception about intervention. Considering the production requirements in the industry and the adoption of static standing position, it might be interesting to develop future research in this type of work environment.

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An Experimental Analysis of Ergonomics in an Assembly Line in a Portuguese Automotive Industry

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Abstract Ergonomic factors have assumed a key role in workers' wellbeing. In industry, these factors become even more crucial considering the potential risk on workers' health due to the monotonous and repetitive nature of tasks, requiring repetitive movements with the same body segment. This is the context of the automotive industry, in particular, the production of automotive components. Also, there is the problem associated with the pressure to workers respond to the cadence imposed by machines. This work emerges from the analysis of the ergonomic' conditions in a production cell of an automotive component industry. The main objective was to identify problems of ergonomic nature in the workstations of the most problematic productive line. First a generalist ergonomic study was conducted in the assembly line, identifying the main ergonomic problems and then specific ergonomic evaluation was performed through the application of methods, such as RULA, Revised NIOSH Equation and Mital Guide. Based on the results, 72.7% of the tasks related with postures and 66.7% of the materials lifting tasks were identified as that could compromised workers' health. Results contributed to plan the industrial improvement processes, specially focused on the ergonomic aspects. Also, they contribute and encourage greater awareness of the importance of the ergonomic aspects on the design and organization of workplaces contributing to the economic and social objectives of the organization.

Keywords Ergonomics · Musculoskeletal disorders · Workplaces · Automotive industry · Assembly lines

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1 Introduction

The concern with the ergonomic aspects, both in work and leisure, has been growing over the years. The impact of ergonomic factors on health has been the subject of several studies that increasingly prove their relevance and how harmful it can be for humans to live in an ergonomically inadequate environment [1].

Work-related musculoskeletal disorders (WMSD) have ranked first in occupational diseases reported in Portugal's most industrialized districts, indicating that the industry, in general, is a sector that greatly enhances the development of these pathologies, given the nature of the work performed in these workplaces [2].

Increasingly, WMSD have been associated with 3 types of contexts: automotive industry; electrical/electronic industry and computer operator [3].

This study is focused on analyzing an industrial environment, where human factor plays a crucial role. In this sense, it was oriented to the automotive industry, more precisely to the production of automotive components. This industry integrates numerous assembly lines that are constantly in automation processes, restricting workers' performance. In fact, workers must only respond to machines' cadence, being seen as an extension of them. The problem lies in the depreciation of the "man" when designing the machines and defining working methods, with most of the attention turned only to the productive component [4].

The automotive components' industry is essentially characterized by the development of repetitive, cyclical, fast, static, monotonous and machine-imposed tasks. As also inadequate postures, application of force, constant pressure in the tissues and absence of adequate recovery. This type of context has been study for a long time, and it is associated with a greater exposure to critical situations [5].

According to data analysis on Europe Occupational Safety and Health (OSH), carried out by Eurostat [6], it was possible to identify some problematic facts:

- Musculoskeletal disorders are the predominant work-related disorders in manufacturing,
- The manufacturing is one of the sectors in which the occurrence of WMSD had the largest increase.

This paper represents part of an investigation carried out to achieve the following objectives "To improve performance indicators in an automotive industry by implementing ergonomic improvements" "To identify problems of ergonomic nature in the workstations of the most problematic productive line" and, "To raise the level of employee' satisfaction with the workplace' conditions". The idea was to identify risk factors that could lead to the possibility of improving some working conditions that in addition to improving comfort and workers' well-being can also boost the performance indicators. Showing that, from the point of view of industrial management, gains can also be made in this aspect. This paper in focused on the last presented objective.

Reflection on the contributions mentioned above may refer to the following scenario if Ergonomics was not present in the design of a particular workstation:

a factory in which several workers with severe damage caused by the work performed are present; low level of motivation of the work team due to the scenario in which they are inserted; conditions that make it difficult to perform certain tasks [7]. Industries that practice their activities in less favorable working environments, such as the scenario described, do not only have problems with workers' health. The vision must be broader to realize that with these consequences the organization itself also has repercussions on its level of productivity and consequently economic [8].

2 Materials and Methods

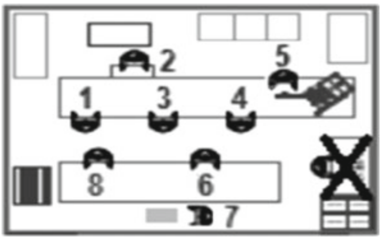
2.1 General Ergonomic Evaluation

On previous work, an identification of the most critical productive cell was done [9]. The line had several workstations. An ergonomic general assessment method "Ergonomic Workplace Analysis (EWA)" was applied, evaluating the workstations that were numbered (from 1 to 7) as shown in Fig. 1. The original guide was used [10] nonetheless, two items were removed: thermal environment and noise, since they were already identified as risk factors and for which the possible control measures have already been established. Most of the evaluation items were classified by direct observation of tasks, using photographs videos. Field data collection, namely weights, distances and times, was also done.

After applying the EWA to each workstation of the production cell, the percentage of the average value obtained in each item was calculated in relation to the maximum value that could be attributed, revealing the distance that a certain factor is from the ideal level.

The illuminance item required an evaluation. This was done based on the guidance of EN 12646-1 [11]. The illuminance was measured in several points of the work plan (a measurement in the center and 4 points around it), to obtain the average value of the work area and the uniformity. The mean values and uniformities were compared with those recommended, verifying compliance. Throughout the evaluation period, workers maintained their normal activity in order to evaluate the amount of effective light that affected the work plan in the normal working

Fig. 1 Workstations numbers of the analyzed line



situation. This procedure was performed only during the daytime period, since the section had no natural light interference, and throughout the day the existing luminosity was always the same.

After the general assessment, a specific ergonomic evaluation was carried out in all the workstations. Different postures adopted by the workers were identified and registered, as well as all the materials manual handling (MMH) tasks. A deeper analysis regarding the risk of WMSD was done in a total of 22 postures and 9 MMH tasks.

For the evaluation of the postures, RULA was applied. This method allowed to evaluate the postures of the neck, trunk and upper limbs, also involving the support of the lower limbs, muscular function and the force exerted by the body [12]. Its application required a direct observation of the task, the movements adopted by each body segment and manipulated loads data. The final score was associated with a level of action that revealed the need for workstation intervention in order to reduce the risk level of workers' WMSD. With the results, the percentage of postures that fit within each action level was calculated. The percentage of postures that needed intervention was highlighted. Within that percentage the incidence of the postures that needed immediate improvements was calculated.

In the evaluation of the MMH tasks, Mital Guide was used. The application of the method followed the correspondent guide [13]. Given the high incidence of WMSD in this production sector, the RWL calculations were performed for the 90th percentile. The calculation of the weights was also directed at the female population, since the great majority of the workers in the line are females and, protecting this group also the majority of male workers are protected. The actual and recommended work rate for each task was also calculated.

Results obtained were analyzed and the tasks that presented a risk of WMSD were counted and their percentage calculated in relation to the total number of MMH tasks performed on the line.

3 Results

The application of the EWA method in the workstations of the productive cell revealed greater criticality in items 10—repeatability (100%), 7—restrictiveness (96.7%), 6—content (93.3%), 11—attention required (91.7%), 4—posture (73.3%), 2—physical activity (70.8%), 12—illuminance (66.7%) and 3—lifting tasks (43.3%). The remaining items showed lower values of criticality.

It was not possible to plan an action in the most critical items (repetitiveness, restrictiveness, content, attention required), because it was necessary to change procedures that the organization did not authorize. A specific study of the second group of most critical items that could be changed in the line, was carried out. Measurement of illuminance levels at the line workstations showed average values ranging from 388.2 to 764 lx, averaging 532.1 lx. The uniformity parameter presented values higher than 0.77. Of the 22 positions adopted by the workers, 6 do not necessarily carry a risk of WMSD. The other postures present risks, as shown in Table 1, where only the most severe results are shown: action level 3 (investigation and changes must occur soon) and action level 4 (investigation and changes are required immediately).

Among the 9 tasks of MMH, 3 revealed an acceptable risk. The Mital Guide method identifies the tasks whose risk is acceptable (R $\leq$ 1), with no need for intervention and the tasks in which there is a risk (R > 1) and need to be redesigned. Table 2 presents the assessments of the tasks that carry risk of WMSD.

Results obtained, both through general and specific ergonomic evaluation were in agreement with the expected one. As indicated by other researchers, the theoretical and experimental context around this theme indicates the frequent presence of ergonomic problems in this industrial sector [4, 5]. The application of the EWA, as expected in this type of manual industrial tasks, reveals the evidence of ergonomic problems in the assembly line. Some of the most critical items are associated with serial production of machines, and cannot be dissociated from tasks, such as repetitiveness, tightness, task content, and required attention. The illuminance levels in the working planes are higher than the recommended ones (300 lx) in

Table 1 RULA results

Workstation	Task	RULA result	Action level
1	Box manipulation (high and low)	7	4
2	Machine operation	6	3
	Box manipulation (high and low)	7	4
	Placement of boxes on the floor	7	4
4	Box manipulation (high and low)	7	4
	Placement of boxes on the floor	7	4
5	Machine operation	6	3
	Pick up the metal bar	6	3
	Put the metal bar in the machine	7	4
7	Pick up cables from the previous workplace to a box	7	4
	Stack boxes (high and low)	7	4
8	Stack boxes	7	4

Table 2 Mital guide results

Workstation	Task	Result
1	Material handling from the racks to the support car	1.57
2	Material handling from the racks to the floor	1.15
4	Material handling from the racks to the floor	1.09
5	Put the metal bar in the machine	1.91
7	Stack boxes	1.40
8	Stack boxes	1.32

values that exceed 88–464 lx, revealing intervention needs. This result would already be expected, since the luminaires are very close to the working planes and are placed without considering the incidence of light in the working plane. The results obtained from EWA method indicated opportunities for improvement in postures, illuminance and lifting tasks, leading to the application of specific ergonomic evaluation methods to identify the tasks/workstations that involved risk and the level of risk.

The majority of postures present a risk of injury: 72.7% require intervention in order to optimize the worker—machine/load interaction and reduce the risk inherent in the performance of the tasks; 59.1% of the positions require immediate changes because they present a high risk of developing WMSD. Analyzing the data obtained, it is evident the need to implement ergonomic improvements in the assembly line.

The majority (66.7%) of lifting tasks pose a risk to workers' health, exposing them to inadequate elevations heightening the risk of developing WMSD. In the tasks described in Table 2, the results of the applied methods indicate the presence of risk for some workers. Intervention is necessary, redesigning the task.

According to the assessments, the need for intervention in these tasks is evident, in order to reduce or eliminate the risk of WMSD associated with materials handling.

4 Conclusions

This experimental study potentially indicates that ergonomic problems still prevail in productive lines in the industrial environment, and ergonomic factors are not a priority for the organization. The ergonomic problems identified in the assembly line under study, which jeopardize the health and safety of workers, are closely related to the illuminance, adopted postures and manual materials handling. Reducing the illuminance incident on workplaces will also reduce the consequences of excessive lighting such as headaches and visual fatigue, improving the comfort of workers. Regarding postures, the situation was very critical. Most of the positions studied require changes in the near future. These results reveal the emergence in the redesign of the workstations, in order to be able to improve the postures, focusing on the height of the machines and equipment, as well as the accessibility to certain areas. The current scenario reveals a high probability of developing WMSD in most of the analyzed tasks.

In general, the loads on MMH tasks far outweigh the RWL. This parameter was not being considered across tasks' planning. It is essential to redesign MMH tasks to reduce the weights, based on the characteristics of each task (handle height, final height, task duration, body asymmetry, or inherent load characteristics), in order to prevent a marked development of WMSD, which will affect not only the health of the workers but also the performance of the productive cells.

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Manual Materials Handling: Case Study at a Portuguese Handling Company

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Abstract Manual Materials Handling (MMH) represents a significant part of the tasks carried out by workers across several economic activity sectors. However, there is a big discrepancy between working conditions and workers actual needs and limitations, and this reflects in the high rate of work-related disorders, particularly, the low back pain, due to incorrect MMH. Ergonomics plays an important role in order to reduce risks associated with MMH tasks, to improve workers safety and health, and, consequently, to raise awareness in organizations and society. It is within this scope, that the present study is presented. It aims to analyze and evaluate risks associated with MMH tasks using four risk assessment methods (MMH Guide, Key Indicator Method, Manual Handling Assessment Charts and Comprehensive Lifting Model). For that, four MMH tasks carried out in two workplaces in the luggage rooms at an airport in Portugal were evaluated. A questionnaire was also developed and applied in order to characterize the sample under study and to understand the company practices regarding MMH. Based on the results obtained, improvement measures were proposed, which can reduce or eliminate the risks associated with the tasks studied, like the implementation of automated or semiautomated loading systems or auxiliary lifting systems.

Keywords MMH · Risk assessment · Baggage handling

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1 Introduction

The incorrect Manual Materials Handling (MMH) is one of the most common causes of work-related musculoskeletal disorders (WRMSD) at low back region [8]. Although it has been declining, the rate of workers that perform tasks involving carrying or moving heavy loads for at least a quarter of their working day is 24% in Portugal. Considering the European Union, this rate is 32% [5]. MMH performance exposes the workers' musculoskeletal system to several risk factors, in particular for the low back region. In the world, 37% of low back disorders are related to exposure to various occupational risks, such as: vibrations, long periods standing up, repetitive trunk movements or twisting movements, like the ones performed in MMH [4].

The aeronautic industry is constantly expanding. According to the International Air Transport Association (IATA), in 2017, passenger numbers increased 7.6% and cargo increased 9.0%, compared to the previous year [12], with growth values above the average pace of the last 10 years [13]. This increase in traffic reflects in the number of bags handled at airport baggage terminals, since, according to the report of the Société Internationale de Télécommunications Aéronautiques, 82% of the passengers surveyed have dispatched at least one bag at check-in counters [22]. In the aircraft industry, IATA [11] identifies baggage/materials handling tasks as the primary cause of WRMSD, particularly for the low back region. Therefore, an appropriate and complete risk assessment of these tasks should be carried out. Ideally, if manual handling of baggage tasks cannot be eliminated through automation or mechanization systems, the workplaces should be designed in order to respect the workers' anthropometric characteristics [2, 16]. However, according to Pikaar and Asselbergs [17], at an airport it is difficult to completely eliminate the manual handling of baggage, and it is estimated that more than 80% of the luggage exceeds the weight indicated as safe by ergonomic recommendations. In a study carried out by Møller et al. [15], the weight of all pieces of checked baggage loaded, on flights departing from Copenhagen airport between 2002 and 2009, was collected, resulting in an average value of 15 kg per baggage. Also, in this study it was estimated that a handling operator, during a work day, carries out tasks involving overweight baggage lifting, in a total between 4000 and 5000 kg. In this field, it is a challenge for Engineering and Ergonomics to find innovative solutions that can reduce the workload of a handling operator. This study aims to analyze and evaluate risks associated with MMH tasks using four risk assessment methods: MMH Guide [14], Key Indicator Method-KIM [23], Manual Handling Assessment Charts-MAC [9] and Comprehensive Lifting Model-CLM [10].

2 Materials and Methods

The study was performed in two baggage terminals in a Portuguese airport. The methodology used in this study involved the design and application to the workers of a questionnaire. Then the characterization of the MMH tasks was performed as well as the selection of workers to participate in the study. To do the risk assessment of the tasks performed by the workers, four methods were selected, namely: MMH Guide, Key Indicator Method-KIM, Manual Handling Assessment Charts-MAC and Comprehensive Lifting Model-CLM. After that, the different outputs obtained with the four methods were compared.

2.1 Questionnaire

The questionnaire was designed to collect demographic data and information on working conditions perceived by the workers responsible for baggage handling at baggage terminals in a Portuguese airport. In addition, it helped selecting the workers whose tasks were analyzed subsequently, so they could be representative of the population. The defined criteria to the selection of the four workers was made considering the potential influence of risk factors regarding to MMH: select at least one worker whose values of age, weight and height were included in the mean of the sample; select at least one worker with more than ten years of experience and one with less than six months of experience; all selected workers work on a full-time basis; a worker with a BMI above the value considered normal. The results obtained by this technique had a descriptive statistical treatment.

2.2 MMH Tasks

The workstations analysed are the arrival and departure conveyors of the baggage terminal, where the workers load/unload baggage to/from the aircraft. To transfer the loads between the baggage terminals and aircrafts baggage cars or Unit Load Devices (ULD) can be used. To define a reference value for a bag, the weight values of 400 bags were collected to estimate a mean value, and was obtained the value of 19.46 ± 4.25 kg (the lowest weight was 6 kg and the highest 31 kg). Therefore, in the current study the reference value for a bag was defined as 19 kg. It should be noted that this value corroborates results of previous studies [15, 17]. The dimensions of the luggage were estimated based on a sample of 20 bags randomly selected: 75 × 40 × 25 cm (length × width × height).

The MMH tasks studied were those with a higher frequency and duration throughout the workday, namely: Task 1: baggage handling from the conveyor to the car (T1) (Fig. 1); Task 2: baggage handling from the conveyor to the ULD (T2); Task 3: baggage handling from the car to the conveyor (T3); Task 4: baggage handling from the ULD to the conveyor (T4). These MMH are all lifting tasks, performed by a worker with both hands. The transport task was not considered since the distance between the conveyor and the transport units is less than 2 m. During the shifts in which the observations were made, T1, T2, T3 and T4 tasks

(a) (b)

Fig. 1 Loading a car (T1), initial position (**a**) and final position (**b**)

were performed, respectively, by W1, W2, W3 and W4 worker. Each task was divided into 8 subtasks, in a total of 32 subtasks.

2.3 Risk Assessment

The methods used for the analysis were selected using the Guide to Selection and Application of Risk Assessment Methods [3]. This guide, with a “decision tree” structure, allows the user to choose the most appropriate method according to the characteristics of the task under study. From hypotheses suggested, the methods were selected by consulting the table adapted for comparison between the seven methods and based on the following assumptions: variety of information given in the outputs, accuracy of the evaluation and highest comprehensiveness possible. Consequently, four methods were selected, namely: MMH, KIM, MAC and CLM.

In order to compare the different outputs obtained for each method, Simões [20] based on an HSE study [7], created an adaptation of the scales consisting in four categories of risk level that converts/standardizes the numerical scales and interpretations inherent to each methods in a single scale (Table 1).

3 Results and Discussion

The questionnaire’ response rate was approximately 64% (169 responses obtained in a total of 265 workers). From the analysis of the questionnaires, it was concluded that all the workers are male, with age between 19 and 60 years, being 64.5% of the workers under the age of 34 and the mean age 31.63 ± 7.92. The mean height is 175.91 ± 6.86 cm, between 156 and 191 cm. The modal class is from 169 to 174 cm (47.3%). The mean weight of workers is 77.71 ± 11.49 kg. These weights

Table 1 Scale adaptation of the methods to the risk level categories

Risk level	MMH guide	KIM	MAC	CLM	Result interpretation
1—Low	R $\leq$ 0.85	TRS < 10	0 $\leq$ TS $\leq$ 4	0 $\leq$ PLSI < 4	No ergonomic intervention required
2—Medium	0.85 < R $\leq$ 1	10 $\leq$ TRS < 25	5 $\leq$ TS $\leq$ 12	4 $\leq$ PLSI < 7	Ergonomic intervention is required in the near future
3—High	R > 1	25 $\leq$ TRS < 50	13 $\leq$ TS $\leq$ 20	7 $\leq$ PLSI < 9	Ergonomic intervention is required as soon as possible
4—Very high	–	TRS $\geq$ 50	21 $\leq$ TS $\leq$ 31	9 $\leq$ PLSI $\leq$ 10	Ergonomic intervention is required immediately

Adapted from [21]
R—Risk; PLSI—Personal lifting safety index; TRS—Total risk score; TS—Total score

are between 55 and 115 kg, with a modal class from 75 to 85 kg, including 39.64% of the workers. The mean Body Mass Index (BMI) of the workers is 25.11 $\pm$ 3.37 kg/m^2 (with the minimum value of 19 and the maximum of 37) and 69 works are considered overweight ($\geq$ 25.0 kg/m^2), 15 of them obese ($\geq$ 30.0 kg/m^2). Concerning the baggage handling at airports, 6 months of work experience can be considered sufficient to handle baggage efficiently (Plamondon et al. 2004) [24]. In the present study, 27.2% of the workers work in the company for 6 months or less, however the higher percentage of workers can be considered experienced (72.8%). With these results, it was possible to verify a high rate of workers turnover in the company.

From the set of the 169 workers that answered the questionnaire, a sample was considered, with four workers, in order to observe and analyse the different MMH tasks performed in the baggage loading/unloading process of the transport units. The characterization of this sample is presented in Table 2.

To assign the risk level associated with each task evaluated, according to the standardized scale, the “result” was calculated. Knowing that the duration of every task was 8 h, the “result” represents the arithmetic mean of the values obtained in the output of the subtasks in each method. Taking as an example T1, the “result” of the MMH Guide is the arithmetic mean of the potential risk values of the eight subtasks of T1, and the value and interpretation of the “result” and level of risk for each task is presented like Table 3.

Table 2 Characterization of the sample of 4 workers

Worker	Age years	Height (cm)	Weight (kg)	BMI (kg/m^2)	Time in the company
W1	45	170	72	24.91	21 years
W2	36	176	100	32.28	4 months
W3	29	169	72	25.21	1 year and 6 months
W4	28	181	81	25.28	1 year and 6 months

Table 3 Summary of risk assessment for T1

Task	Method	Result	Risk level	Result interpretation
T1	MMH Guide	1.54	3 - High	Ergonomic intervention is required as soon as possible
	KIM	70	4 - Very High	Ergonomic intervention is required immediately
	MAC	16	3 - High	Ergonomic intervention is required as soon as possible
	CLM	10	4 - Very High	Ergonomic intervention is required immediately

For all tasks, the risk level always varies between 3 (high risk) and 4 (very high risk) according to the applied method. However, it is not possible to highlight which of the four tasks represents a higher risk to the workers since the risk level values are very similar. All methods evidence the need for ergonomic intervention in workstations in order to eliminate/reduce risks.

The KIM method classified all the tasks under study as very high risk, considering that the four tasks correspond to high load situations where the physical overload of the worker is probable and ergonomic intervention is required as soon as possible/immediately. The MAC, KIM and MMH Guide showed more sensitivity and precision in distinguishing the physical characteristics of the workers. Also, for the same subtask of the four tasks under study the risk level obtained was the same. However, considering the individual risk factors, the ability of W1 worker to perform MMH tasks can be compromised by his age (45 years), since the maximum muscle strength for males is reached between 25 and 35 years, decreasing from that age on Grandjean [6]. The CLM is more sensitive to individual variations, since it was the only one that presented different levels of risk in the comparison of the four tasks, and due to its precision of analysis which took into account the workers physical characteristics. In this field it should be noted that the T2 was developed by an obese worker (BMI = 32.28 corresponding to level I of obesity). The physical constitution of the worker may have been an important risk factor during MMH, since people with obesity are more predisposed to the appearance of postural alterations and development of spinal injuries [21]. In addition, the W2 worker may also be in a disadvantageous situation compared to the other workers, since he has been working in the company for less than 6 months and the strategies adopted by less experienced workers are different from those adopted by workers with more experience, in particular regarding to flexion of the spine and knees during lifting, load balance and control, and efficient use of the load thrust during handling [1, 18, 19]. With the CLM, it was verified that a lower manipulation frequency value translated into a lower value of risk associated with T2. However, it was not possible to corroborate the assumptions that indicate the increased risk associated with the individual characteristics of the workers in the MMH tasks.

Based on the identified variables/factors, improvement measures were proposed in order to reduce/eliminate the risks associated with MMH tasks: technical or engineering measures and organizational measures. In the luggage terminals, auxiliary lifting systems are the quickest solution to implement since they are easily integrated into systems that already exist and can significantly improve the efficiency and quality of the handling process in the luggage terminals. Pikaar and Asselbergs [17] concluded that this type of systems, if installed in only two luggage huts, combining with rotation of tasks, reduces the physical overload of the workers by 12%. In the work stations under study, the implementation of semi-automated systems could be done at the departure conveyor in order to assist the loading of the transport units. The operator only needs to move the system to the location on the transport unit where he wants to place the luggage.

The organizational measures were suggested according to the situation to be addressed, namely, task characteristics (alternate baggage loading/unloading tasks with transport tasks from the transport units to the aircraft; workstation rotation; work shifts requirements; selection of the workers suitable for the work; scheduled breaks), load characteristics (heavy luggage signalling; weight limits; baggage format standardization) and characteristics of the work station and transport units (training and information about MMH techniques; transport units design and utilization; height of conveyors).

4 Conclusions

With the questionnaire analysis, it was concluded that exists a high rate of workers turnover in the company. The results obtained in the application of the four methods indicate risk levels between 3 (high risk) and 4 (very high risk) in the four tasks, which means that the workers are exposed to a significant risk level when performing the handling tasks commonly present in the airports. The results showed that the use of different assessment methods allows them to complement each other, since each method considers different criteria and risk factors. All methods evidence the need for ergonomic intervention and that it is important to introduce engineering measures in order to control the risks related to MMH in airports like.

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Integration of Ergonomics in the Study of Catenary Execution Projects

Francisco Salguero-Caparrós, María Martínez-Rojas, María del Carmen Pardo-Ferreira and Juan Carlos Rubio-Romero

Abstract The railway industry is exposed to high levels of risk, work under pressure and a large margin to the unpredictable when remodelling works are carried out. The aim of this study is to analyse and evaluate the railway activity, specifically those that uses catenary technology, from an ergonomic point of view during the excavation, concreting and pole raising phases. In order to do this, a workplace during the catenary assembly procedure was analysed using the OWAS method. The application of this method to the mentioned procedure showed that the most outstanding ergonomic risks are those related to load handling, repetitive movements, application of force. In addition, this procedure involves important forced and continuous posture of trunk flexion. These results indicated that with feasible ergonomic changes, the design of the equipment or the tasks and/or its planning, they could considerably improve the working conditions. Therefore, musculoskeletal disorders could reduce by implementing measures from the early engineering phase.

Keywords Ergonomics · Musculoskeletal disorders (MSDs) · OWAS method

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1 Introduction

The construction industry is exciting and demanding, and the railway in particular, combines high demands at the risk level, work under pressure and a large margin to the unpredictable [1], especially when it comes to remodelling works, as it happens in most cases. An important technological change taking place in the railways generates new safety concerns. The speed with which the change occurs along with the technological trends is significant for an industry that can have important consequences when things go wrong. For this reason, it is essential to raise awareness about the possible health and safety risks that arise in the railway industry [2]. Likewise, intervening in railway-electrified lines includes the difficulty of not having the real starting data of the state of its construction, which forces to omit the theoretical studies in execution phase adapting the valid solutions just at the moment of action [3].

In the railway installations, the catenary is defined by Hutter [4] as the system that provides electric power to the traction vehicles through rail using the pantograph. For this, the assembly or disassembly of the catenary has been analysed fundamentally from the perspective of an electrical accident within this industry [5]. However, fatigue is an issue that has been studied in a laboratory environment, but it is still difficult to apply in an industrial setting [6].

The European Directive 89/391/CEE of the Council, of June 12 [7], on the application of measures to promote the improvement of safety and health of workers at work, indicates in its article 6 that the first obligation of employers to workers is "to adapt the work to the person, particularly in regard to the conception of jobs." Accordingly, in the analysis of working conditions is essential for the recognition of ergonomic and psychosocial factors, their evaluation and further deepening in the treatment of them.

In this sense, as noted by the European Agency for Safety and Health at Work [8], musculoskeletal disorders (MSDs) are one of the most common work-related ailments. Thus, according to the latest survey on working conditions of the National Institute for Safety and Hygiene at Work in Spain [9], musculoskeletal disorders are one of the main complaints of workers.

During the construction or reform of catenaries, workers must be prepared to analyse situations and act accordingly. To do so, workers should have a wide range of procedures in which general aspects are contemplated, in terms of both safety, quality, and organization at work. These aspects are essential to avoid negative effects on workers and the overall results of the activities. Hence the idea of taking part also from an ergonomic point of view to address railway work arise [10]. Therefore, it seems logical to warn of its ergonomic risks, just as other branches of safety are studied [11]. Despite this, in relation to training for catenary operators, there is no compulsory procedure or training in Europe according to the EU Framework Directive in terms of safety and health.

The phase where a lack of adequate procedures has been identified is studies and engineering projects [12, 13]. During the tender process, companies are limited to propose generic on-site execution procedures, which do not contemplate the inherent risks of work that negatively influence the worker's ergonomics [14, 15]. In most cases, it implies a less optimal work, with lower quality, and worse results in times and solutions adopted, because the quality of the human factor that performs the tasks, is essential for the proper development of these [16].

This global process required for ergonomic change, which is intended to submit an infrastructure and organization, in the case that concerns us, the railway, has to consider general and specific aspects in the two main sides of a project: the owner and the client. Even though both, not primary concerns when it comes to asses ergonomics matters related to work environment and human safety. Therefore, an important part in this sector is to anticipate the critical observation points [17–20], to be able to repair them and act accordingly. Ideally, previous specific training that unites the studies that arise since the return of experience in the field.

Therefore, the aim of this study is the analysis and evaluation of the railway activity, specifically of catenary technology, at an ergonomic level during the phases of excavation, concreting and hoisting of poles. For this purpose, the OWAS method was used. Based on this objective, the following research question arises: to what extent can the integration of ergonomics in the engineering phase, anticipate a greater number of risks and optimize the work for people and for the organization?

2 Methodology

This study has been carried out based on works of execution of catenary works, in which electrical traction installations were built or remodelled during the second quarter of 2017. In particular, the analysis is carried out from the point of view of ergonomics a workplace in the catenary execution sector; specifically during the catenary assembly procedure proposing corrective measures so that these risks are eliminated or reduced. To evaluate these work tasks, five workers participated as volunteers in the field measurements. Each of these workers had more than ten years of experience in the execution of this type of tasks.

2.1 Ovako Working Analysis System (OWAS)

Within the existing methodologies in occupational health and safety, many methods can be used to perform a postural evaluation of the different activities [21]. In accordance with the Manual of ergonomics applied to the Prevention of Occupational Risks [22], when movements of extension, abduction, flexion less than 60° or abduction of the arm and movements of extension or flexion of the neck less than 40° are adopted, an evaluation should be made with level II methods, among which is the OWAS method.

This method was developed by Karhu et al. [23], being a simple and useful method for the ergonomic analysis of poor working postures. Its application provides good results, both in the improvement of the comfort of the workplaces and in the increase of the quality of the production, consequence this one of the applied improvements. The method consists of two parts. The first consist on an "in situ" observation of the worker to evaluate work postures. In the second part of the method, a set of criteria for the redesign of methods and workplaces are defined. The criteria are based on evaluations carried out by experienced workers and experts in ergonomics.

The reason why this method has been chosen is because it allows identifying a large number of positions that a worker adopts when performing the task. It differences up to 252 positions in which the position of both lower and upper extremities is considered and the trunk. In addition, it analyzes the forced postures in the whole body, together with the load handled, which is of our interest. Definitely, the OWAS method is characterized by its capacity to assess globally all the postures adopted during the performance of the task [24].

2.2 Development of the OWAS Ergonomic Method

For the ergonomic analysis of the most characteristic postures in a catenary assembly process, in the application of the OWAS method, the exposure of the operators to risk factors derived by postures in the upper and lower limbs of the body under repetitiveness of movements under loads was evaluated. In the selection of the work postures analysed, those that move away from the normal position were taken as a reference, being considered as harmful for the musculoskeletal system, selecting only those that seemed to harbour a higher postural load.

Using the tables associated with the method, a score was assigned to each body area (back, legs and arms) for, depending on these scores, assign global values, which were subsequently modified at the rate of muscle activity developed. The final value provided by the method is proportional to the risk involved in carrying out the task, so that high values indicate a greater risk of the appearance of musculoskeletal injuries, and thus knowledge is obtained about the corrective measures that are going to be proposed. The proposed action levels ranged from level 1, which estimates that the evaluated position is acceptable, to level 4, which indicates the urgent need for changes in activity.

As previously explained and as can be shown in Table 1, the following specific evaluation tasks were carried out by the worker throughout his working day during the assembly work of catenaries, which are classified according to the following phases:

Table 1 OWAS method work evaluation tasks

	Station phase	Task	Task phase
Previous works	1	Taking security measures	1.1
Previous works	1	Drill poles	1.2
Previous works	1	Pre-assembly	1.3
Previous works	1	Pole collection	1.4
Previous works	1	Retention installation	1.5
Concreting and lifting	2	Evacuation	2.1
Concreting and lifting	2	Excavation	2.2
Concreting and lifting	2	Guided poles	2.3
Concreting and lifting	2	Lifting	2.4
Concreting and lifting	2	Concreting	2.5
Concreting and lifting	2	Collection	2.6

3 Results

The application of the OWAS method to the catenary assembly procedure has interpreted the postural analysis of each task, where after coding and rating the positions of the positions involved, the ergonomic risks are identified according to the tables of the OWAS method introduced in the development of the Ergonomic method (Table 2).

As can be seen in Table 2, the most prominent ergonomic risks in catenary assembly tasks are those in which important forced and continuous postures of

Table 2 Results risk level by OWAS method

	Task phase	**Risk level**
Taking security measures	1.1	1
Drill poles	1.2	4
Pre assembly	1.3	4
Pole collection	1.4	4
Retention installation	1.5	2
Evacuation	2.1	3
Excavation	2.2	1
Guided poles	2.3	4
Lifting	2.4	4
Concreting	2.5	2
Collection	2.6	2

trunk flexion have been identified. In the phase of previous works, it is worth mentioning the drill poles, pre-assembly and pole collection.

Likewise, in the concreting and lifting phase it is also worth noting with level of risk 4, those tasks in which the back suffers a lot as in the tasks of guiding poles or vain supports (Fig. 1) and lifting poles (Figs. 2 and 3). In this phase, the flexion of arms and back joins the handling of a high and unbalanced load.

Fig. 1 Image of guided poles or vain supports

Fig. 2 Image of lifting pole

Fig. 3 Image of the placement of the struts

4 Discussion

In this study and as already advanced Karwowski and Mital [25], there have been indications and data that suggest the existence of problems caused to the worker of musculoskeletal type and that have as origin the lack of ergonomic application in the work. Specifically, and as maintained by Pezzillo et al. [11], it was revealed that the most prominent ergonomic risks are those related to load handling, forced postures, repetitive movements and application of force, with the handling of suspended loads. Therefore, the answer to the research question initially raised is answered as to the extent to which the integration of ergonomics from the engineering phase, can foresee a greater number of risks and optimize jobs for people and for the organization.

It should be noted that, in the assembly work of railway catenaries, operators are subjected to a great postural load as a consequence of the enormous flexion to which they are exposed to the back. Lower and upper limbs adopt very forced postures in the face of great loads and in an unbalanced way. The inclination of the back is practically inevitable. For this, the way to reduce the damage would be to establish operator rotation and pauses between the guidance of different poles, so that the workers are not exposed for a long time to the twists and turns of the trunk, as well as kneeling and squatting postures. It is a task in which habitually, it has been possible to accumulate delays in the times, and this causes the overexertion of the workers without rotating or resting so as not to delay the planning more.

Definitely, proper time planning from the engineering phase can reduce the ailments that occur with these positions. This planning must be real in time and not unattainable milestones. The margins should be generous, and not focus on the task without correctly foreseeing the number of operators needed. According to the number of poles, more work teams will be established at the same time, or the time with the same number of workers will be increased.

Therefore, and confirming the findings of Crawford and Kift [2], it is recognized that the railway industry has a unique opportunity to take advantage of the lessons learned by other industries. This learning would facilitate the integration of organizational ergonomics in socio-technical systems, in topics such as management of the hierarchy of positions, levels of responsibility, roles or human resources among others.

5 Conclusions

It has been observed the existence, in this particular sector of railway construction, of a number of ergonomic risks that are sometimes not easy to detect, and what is worse, they are not easy to solve. Beginning with this problematic, the need to study ergonomics has emerged, which is the relationship between man and his working conditions; in order to try to mitigate the negative effects created in those circumstances.

With the application of this method and the results extracted, it can be concluded that almost all the tasks evaluated are in a category of high and even very high ergonomic risk. According to this level of risk, the corresponding preventive measures should be proposed in order to eliminate or mitigate risks and preventing the appearance of musculoskeletal disorders.

Normally, feasible ergonomic changes, the design of the equipment or the tasks and/or its planning, can considerably improve the ergonomics of the workers. According to the results obtained, musculoskeletal disorders (MSDs) could reduce by implementing early stage measures in the course of a work, since the first engineering phase.

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Posture Analysis of a Typist's Workstation

Alan Gurgel Saraiva and Luiz Bueno da Silva

Abstract Working with typing requires the professional to spend many hours sitting in front of a computer, doing repetitive movements, with no breaks or with small rest periods. For this reason, typists are subject to contracting diseases in the musculoskeletal system. This study aimed to study the work of a typist from a public office in the state of Paraíba, Brazil. The methodologies used were Rapid Upper Limb Assessment (RULA) and Rapid Entire Body Assessment (REBA). Although they are old and with limitations, the RULA and REBA methodologies are still widely used to study musculoskeletal system diseases in workers. It is worth mentioning that the typist's work place has undergone renovations recently due to the high index of repetitive effort injuries and Work-related musculoskeletal disorders (RSI/WMSDs) and also by planning the public institution itself. This work began after the completion of these structural reforms because the authors sought the public institution for the studies when the works had already begun. The level of risk related to posture in the workplace studied was 3 for both the RULA and REBA methodology, which represents a low level of risk. Despite the low level of risk of contracting RSI/WMSDs, it would recommend further reforms and changes in jobs in the future.

Keywords Typist · RULA · REBA · Workstation · Posture analysis

1 Introduction

According to several studies, consecutive hours of computer work, reduced frequency of rest breaks and long duration of sustained posture during this type of work have been positively associated with musculoskeletal symptoms [9].

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For Bisht and Bakhshi [2], working on a computer involves sitting in only one position for long hours and requiring repetitive movements. Performing repetitive work with short pauses, or even no interval, is one of the main causes of Repetitive Strain Injury and Work-related musculoskeletal disorders (RSI) in the work environment.

In a study carried out by Callegari et al. [3], one of the conclusions was that performing pauses for resting the hand can successfully reduce the risk of contracting WMSDs during prolonged typing, due to the resting of the tired hand muscles. Regarding pauses in the work environment, Luger et al. [8] state that their goal is to interrupt or diminish long periods of repetitive or monotonous work and periods when workers need to adopt awkward postures.

Waongenngarm et al. [14] classify work breaks into four types: active interruptions with postural change, active interruptions without change of posture, passive breaks and permanent breaks during computer work. Despite being old-fashioned, the Rapid Upper Limb Assessment (RULA) and Rapid Entire Body Assessment (REBA) methodologies are still widely used for postural studies of workplaces.

These methodologies were developed by McAtamney and Corlett [10] and Hignett and McAtamney [5], respectively. Both aim to study the risks of diseases in the musculoskeletal system relating to muscular effort associated with static or repetitive work posture, and that may contribute to muscle fatigue. Both are made through observations with video recording or photographic record.

For Bao et al. [1], studying posture measurement using observational methods is a practical and reasonably reliable tool in musculoskeletal epidemiological research.

The present study aimed to analyse the posture of a typist from a public office in the state of Paraíba at his work, using the RULA and REBA methodologies.

2 Methodology

The current study is a pilot study which started in August 2018 just after a reform which was already scheduled by public institution. The old place that the typist team used to work had a high level of Musculoskeletal disorders (MSD) because of its location. The location was next to a garage, there was too many noise in the local and this affected the typist team performance negatively because they couldn't focus on their work, also the workstation of some typists weren't in a good location in the old place because the place used to be very crowded most part of the time and those typist had to do unwanted postures to allow people walk around. Because of those reasons the levels of risk before the reform was high.

The new Works station is located in a new room further from the garage that just the typist team is allowed to inter into this room. The new room is air-conditioned, the noise levels does not affect the typists performance, the typists' workstations are well located and problems that used to happen when the old workstation was crowded will not happen again but there are some typists who still complains about Musculoskeletal disorders (MSD).

The work station studied has a table with a height of 0.75 m, length of 1.6 m and a depth of 0.6 m, with capacity for two typists to use at the same time. The workstation chair can range from 0.48 to 0.6 m, has a depth of 0.5 m and a backrest height of 0.6 m.

A 24-year-old young shorthand student was selected for this study and has been practicing the profession of typist shorthand for 3 years. Despite being young, this stenographer already complains of pains in the musculoskeletal system in the regions of the neck, left shoulder, and left hand.

The typist team has a dual role in this public institution: stenographer and typist. However, only the typing station will be analyzed in this study. For this study, weekly visits were made during two months in the institution, to know the work routine of the typists, their jobs and their tasks.

For the application of the RULA and REBA methodologies, records were taken with photos and filming of a staff member doing typewriting at their job. After that, those records were seen and watched several times to analyze the typist's posture and the angles of his body while he works. Figure 1 illustrates the typist studied at his work station.

3 Results and Discussions

Typists are in static movement, seated, and making repetitive movements in the upper limbs, typing work. The typists are responsible for typing meetings, sessions, and assemblies that occur in the public office. Photos 2, 3 and 4 show the studied typist working from several angles.

Fig. 1 Typist at his workstation

The results of risk assessment of the RULA and REBA methodologies were the same, evaluated as 3. This means that risks of RSI/WMSDs are low, but changes may be necessary at the workplace. Tables 1 and 2 show the risks of disease in the musculoskeletal system according to the RULA and REBA methodologies, respectively.

The typist studied raises shoulders frequently during the typing process. The worker is not exposed to a serious risk of contracting RSI/WMSDs because of the typing task performed at work. The typist's working conditions proved to be adequate (Fig. 2).

Incidentally, the pain in the shoulders that the typist feels may be caused by various work-related reasons. According to Côté et al. [4], the main causes are: posture and workstation modifications through ergonomic interventions; the posture of the head, shoulder and elbow during typing; the use of the computer mouse, which takes the shoulders to be flexed to more than 25º; a distance from the edge of the table to the "J" button bigger than 12.5 cm is associated with a small reduction in the incidence of neck/shoulder pain. Miranda et al. [11] affirm that personal factors of the worker also contributes to the appearance of shoulder pain.

Already Ranasinghe et al. [12], who conducted a study with office workers who work most of time with typing, concluded that it is common for people working with typing to complain of pain in the arms, shoulders and neck. According to the same authors, physical factors related to work, psychosocial factors and lack of awareness are the main reasons for complaints of pain in musculoskeletal system (Fig. 3).

Table 1 Level of disease risk in the musculoskeletal system, according to the RULA methodology

Score	Level of MSD Risk
1–2	Negligible risk, no action required
3–4	Low risk, change may be needed
5–6	Medium risk, further investigation, change soon
6+	Very high risk, implement change now

Table 2 Level of disease risk in the musculoskeletal system, according to the REBA methodology

Score	Level of MSD Risk
1	Negligible risk, no action required
2–3	Low risk, change may be needed
4–7	Medium risk, further investigation, change soon
8–10	High risk, investigate and implement change
11+	Very high risk, implement change

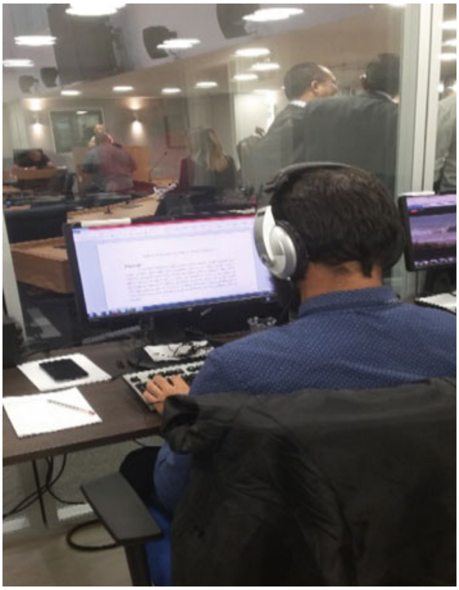

Fig. 2 Picture taken on the left side

Fig. 3 Photo taken behind the typist

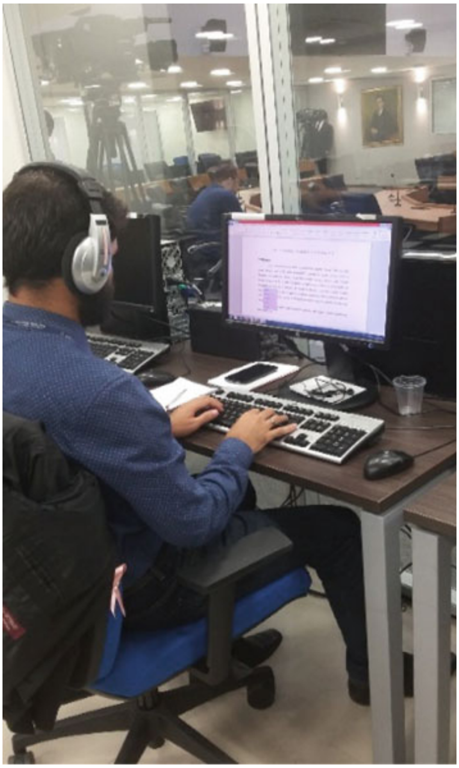

Fig. 4 Photo taken on the right side

Further studies on the typist's posture and his work station need to be performed to find out the true cause of the typist's shoulder pains (Fig. 4).

4 Conclusion

According to the RULA and REBA methodologies, the risks of contracting diseases in musculoskeletal system of the studied workplace were classified with a grade 3 in both, which represents a low level risk. It is worth mentioning that this study began to be carried out after a period of structural reforms in the workplace, precisely to prevent cases of RSI/WMSDs among typists and to modernize the workstations of the public institution, it was a request of the public institution.

Even with a low risk of developing musculoskeletal diseases and the workplace has undergone structural reforms recently, It is hoped that this study will contribute to the improvement of the workplaces of the typists' stenographers in the public office studied because there is still a need for further reforms in order to prevent RSI/DTS cases. Because it was a pilot study, it was only necessary to study a job.

To reduce the left shoulder pain and the hand left pain in the typist, it was recommended to perform physical exercises on work environment during break times. Many studies have concluded that performing physical exercises on work environment is efficient in reducing pain in the musculoskeletal system [6, 13].

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Effects of Noise Frequency on Performance and Well-Being

Jorge Sousa, Raquel Monteiro, David Tomé and Matilde A. Rodrigues

Abstract The features of occupational noise, in particular sound pressure levels, the type of noise and its frequency can be related to several physiological and non-physiological effects. However, studies about the influence of occupational noise on non-physiological effects are still scarce. The aim of this study was to investigate effect of intermittent sound patterns with different frequency on subjects' performance and well-being. Five conditions were simulated and tested through an experimental study: Standard Condition (C0); Industrial noise with alert sounds at 500 Hz (C1); Industrial noise with alert sounds at 1000 Hz (C2); Industrial noise with alert sounds at 2000 Hz (C3); Industrial noise with alert sounds at 3000 Hz (C4). The noise levels were fixed at 45 ± 0.3 dB (A) in C0, and in 68 ± 0.5 dB (A) in the other conditions. The influence of noise on participants' attention and short-term memory was assessed with the serial recall and response inhibition tests. Discomfort, stress and annoyance were accessed using Visual Analog Scales (VAS). Sixteen undergraduate students were included in this study

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(8 male; age: M = 22.25 yrs; SD = 0.7 yrs). Higher discomfort, stress and annoyance perceptions were found in condition C4; however, for task performance, no significant differences were found between conditions. This study provided important insights about the influence of different noise frequencies on subject's performance and well-being. Future research should involve workers and how they react in the field to these conditions.

Keywords Annoyance · Discomfort · Occupational noise · Noise frequency · Performance

1 Introduction

Increasing employees' productivity and efficiency, without affecting their safety and health, is one of the most important challenges for companies. In fact, employers need to realize that ensure safe and healthy workplaces for their employees is not only a legal requirement, but also an important strategy to improve proficiency and enhance the company's image and brand. However, it is broadly recognized that several persons work under inappropriate environmental conditions, i.e., inappropriate thermal environments [1], workplaces with poor lighting [2], vibrations [3, 4], occupational noise [5–8], among others. Beyond the well-known health effects, occupational exposure to these hazards can also affect employees' performance and well-being [4].

Noise is one of the most important occupational risk factors identified in the literature. Exposure to high sound pressure levels results in damages to the auditory system [9]. Additionally, it was related to several negative non-physiological effects such as annoyance, stress and discomfort [10–12], impaired conversation [11, 12], as well as negative effects on attention and working memory [13, 14].

The relation between the noise exposure and employees' performance is not a simple matter. According to Banbury et al. [15], the type of noise and its characteristics, as well as the cognitive task being performed mediates the influence of noise on subjects' performance. The randomness of patterns in intermittent sounds showed that errors rates can differ [16]. Clark and Stansfeld [17] state that this type of noise have a higher significant impact in cognitive performance than steady continuous sounds. Nassiri et al. [7] found that intermittent noise with intensities of 85 dB are more likely to cause errors at the speed response levels. On the other hand, Lercher et al. [18] showed that continuous noise had lower effect during complex tasks, like the ones that require working memory, in comparison with intermittent noise. Sound pressure levels are also frequently noticed as an important noise characteristic that can have a negative effect on employees' performance. Nassiri et al. [7] found that sound pressure levels at 95 dB can increase the amount of errors. Alimohammadi et al. [19] found that performance time decreased in an environment where noise was present comparatively to a noiseless one. However, the same authors not found differences in performance when noise levels were between 50 dB (A) and 70 dB (A). Previous studies also showed that at the same sound pressure level, the difference in the frequency may have different effects on subjects' performance. Nassiri et al. [7] verified that high frequencies can lead to a decrease in precision in task completion. However, low frequencies can also be harmful, increasing workers fatigue [20]. In view of this, it is of particular importance to take into consideration sound pressure levels, noise type and frequency when workplaces are being optimized and designed in order to improve employees' performance.

Despite the importance of occupational noise in workers' performance and well-being, studies about this subject are still scarce. Therefore, the aim of this study was to investigate effect of intermittent sound patterns with different frequency on subjects' performance and well-being.

2 Methodology

2.1 Participants

The present study included 16 undergraduate school students, who volunteered to participate. The participants were aged between 21 and 23 (M = 22.25; SD = 0.7; 50% male; 50% female). Inclusion criteria for this study was normal hearing, lack of visual disorders, non-smoking, lack of sleep disorders in the past 24 h and absence of mental health disorders. This information was obtained through questionnaires. Information about the questionnaires applied are further described in Monteiro et al. [13]. All the experiments were done ensuring that the subjects had slept at least 7 h the night before.

The study was approved by the Ethical Committee of the institution where it was carried out.

2.2 Procedures and instruments

In order to respond to the defined objectives, an experimental procedure that involved 5 acoustic conditions was designed: (C0) Standard condition 45 ± 0.3 dB (A); (C1) Industrial noise with alert sounds at 500 Hz 68 ± 0.5 dB(A); (C2) Industrial noise with alert sounds at 1000 Hz 68 ± 0.5 dB(A); (C3) Industrial noise with alert sounds at 2000 Hz 68 ± 0.5 dB(A); (C4) Industrial noise with alert sounds at 3000 Hz 68 ± 0.5 dB(A).

For the experiment, an audiology laboratory was adapted to create a simulated environment. A desk, which allowed each participant to be seated during the tests, was placed in the room. Four speakers, two on the front and two on each side were placed around the desk, projecting recorded environmental noise collected by

Monteiro et al. [13] in a previous study and producing the other alert sounds. Under each noise condition, subjects were asked to complete two tests: Serial Recall and Response Inhibition. After each trial, a visual analogue scale (VAS) was used to measure the discomfort, stress, annoyance, sound perception of the stimulus and interference with the tasks at hand. The VAS consisted of a line with 100 mm in length, labelled at each end as "Not at all…" at the left end, and "Extremely…" at the right. Subjects were asked to mark across the line the point that indicated the level of discomfort, stress, annoyance, sound perception, and interference that they were feeling. Since the sound perception and the interference parameters were allusive to the stimulus, they were not measured on the C0 noise conditions. Sound pressure levels were monitored with a CESVA SC310 Sound Level Meter. According to the intermittent sound frequency, sound pressure levels were adjusted in order to achieve the target of 68 ± 0.5 dB (A).

2.3 Data Analysis

Nonparametric Shapiro–Wilk test was used to test normality. Subsequently, since normality assumptions were violated, comparisons of the means were made using the nonparametric Wilcoxon test and Friedman's test. Correlation was analyzed using Spearman's correlation coefficient. A significance level of $\alpha = 5\%$ was considered in the present study. All analysis were performed using the statistical software package Statistical Package for Social Sciences (IBM SPSS®) version 23.

3 Results

Regarding the results of the experiment, Table 1 presents the descriptive statistics and compares the results of different parameters in the five noise conditions.

No significant differences were observed between the different noise conditions for Serial Recall and Response Inhibition tests ($p > 0.05$). Similar results were obtained for the stimulus perception and perceptions of the interference of stimulus ($p > 0.05$). However, in what regards to discomfort, stress and annoyance results shows significant differences between the conditions under analysis for these variables ($p < 0.05$).

Data suggests that as the stimulus frequency increases, the discomfort, stress and annoyance levels also increase. In the condition C4 were observed the higher levels of discomfort (55.06 ± 26.06), stress (43.25 ± 32.89) and annoyance (63.56 ± 32.14). It was also observed that the parameter annoyance did not increase in a steady way. The condition C2 presents a higher rate of annoyance (55.06 ± 32.59) than the condition C3. The condition C0 showed the lowest values of discomfort (13.93 ± 21.9), stress (17.56 ± 19.33), annoyance (6.43 ± 13.25), perception of the stimulus (59.75 ± 28.07) and interference (40.5 ± 27.33).

Table 1 Summary of results for the different parameters in the five noise conditions

Parameter	Noise condition	Mean	SD	*p*-value
Serial recall errors	C0	7.75	5.77	0.292
	C1	7.56	7.56	
	C2	5.94	3.15	
	C3	7.94	6.01	
	C4	6.25	4.14	
Response inhibition commission errors	C0	0.38	0.81	0.655
	C1	0.38	0.71	
	C2	0.81	2.74	
	C3	0.75	0.86	
	C4	0.69	1.07	
Response inhibition omission errors	C0	0.37	0.50	0.081
	C1	0.25	0.58	
	C2	0.18	0.40	
	C3	0.19	0.54	
	C4	0.25	0.45	
Discomfort level	C0	13.93	21.90	0.001
	C1	45.18	29.80	
	C2	44.18	28.79	
	C3	44.00	28.35	
	C4	55.06	26.06	
Stress level	C0	17.56	19.33	0.001
	C1	34.93	31.68	
	C2	39.68	30.15	
	C3	37.62	28.72	
	C4	43.25	32.89	
Annoyance level	C0	6.43	13.25	0.000
	C1	47.43	34.11	
	C2	55.06	32.59	
	C3	48.00	32.35	
	C4	63.56	32.14	
Perception level	C0	–	–	0.760
	C1	59.75	28.07	
	C2	60.68	24.79	
	C3	60.12	29.90	
	C4	61.56	23.18	
Interference level	C0	–	–	0.713
	C1	40.50	27.33	
	C2	48.18	29.57	
	C3	42.87	25.47	
	C4	49.12	27.38	

Note C0—Standard condition; C1—Industrial noise with alert sounds at 500 Hz; C2—Industrial noise with alert sounds at 1000 Hz; C3—Industrial noise with alert sounds at 2000 Hz; C4—Industrial noise with alert sounds at 3000 Hz

Significant pairwise comparisons were found in the parameters discomfort, stress and annoyance ($p < 0.05$).

In condition C0 a positive correlation was observed between discomfort and stress ($r = 0.555$; $p < 0.05$). In all other conditions, positive correlations were observed between discomfort, stress, annoyance and interference with tasks ($p < 0.01$).

4 Discussion

The experimental study focused on the analysis of subjects performance and well-being on five different conditions of noise. No significant differences between the five different noise conditions were found for Serial Recall and Response Inhibition test results. Both the fact that students were included in this experiment instead of workers and the limited sample used can have contributed to these results. It was expected to find differences between the standard condition and the conditions where the intermittent stimulus was produced. The study conducted by Monteiro et al. [13] showed that under the condition with noise and intermittent stimulus at 1000 Hz (C2) the number of errors increased when compared to the standard condition (C0) or the condition without environment noise. This was not observed in the present study. One explanation for the results can be the arousal theory. Arousability represents the activity of the central nervous system and it fluctuates between sleep and alertness, adjusting the response to stimulus [21]. Maybe if a more extensive range of sound pressures and frequencies were used in this research, the performance would be different. Adding to uncertainty of results, there has been a debate whether the range of 600 Hz and 4000 Hz has the most effects like sleep disturbance, hypertension, and noise induced annoyance as well as fatigue and lack of concentration that can interfere with tasks [22]. It is important to note that between the frequencies of 500 and 3000 Hz exists a higher risk of hearing-loss as well [23].

The present study also found out that discomfort, stress and annoyance perceptions increased significantly with the frequency of the stimulus. In all the three parameters the condition of 68 ± 0.5 dB (A) with stimulus at 3000 Hz (C4) had the higher values in each scale. According to Salvendy [24], human hearing is its most sensitive at the range of 4000 Hz, so being the C4 the condition that approximates the best to that range with 3000 Hz, the results can be compared. This also explains the non-significant differences in the perception of the stimulus scale. Another study by Ménard et al. [25] showed that the perception of sound differs insignificantly with changes in the frequency at the same sound pressure levels. However, it is important to note that in the condition C2 the parameter annoyance presented a high value compared to condition C3 and C1 although no studies were found that explained this phenomenon. According to Kumar et al. [26], discomfort is more associated with sound frequencies between 2400 and 5500 Hz. The results also suggest that exists a relationship between the annoyance, stress, discomfort and interference. Similar results were previously found by Monteiro et al. [10].

5 Conclusion

The objective of the study was achieved, giving insights about the effect of the different sound frequencies on subjects' performance and well-being. These results are important to design control measures, in particular changes in alert sound emitted by machinery in a fast food restaurant. Despite the results showed that no significant differences were found in subject's performance, this can mean that the frequencies tested does not have a significant impact in the performance of tasks that require attention and short-term memory. These findings show that alarms and intermittent sounds with frequencies like the ones used in this research do not have direct effects on subjects' performance. However, there is an important impact on subject's discomfort, stress, and annoyance, which increased with higher frequency stimulus, possibly interfering with workers concentration and increasing fatigue with the time of exposure.

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Lighting Assessment at Workplaces in a Granite Manufacturing Company

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Abstract The workers' safety and wellbeing is the key to achieve higher levels of productivity and efficiency. An adequate lighting is one of the factors that influences the workplace and consequently, the comfort and satisfaction of the workers. This study aims to assess the lighting quality at seven work sections in a granite company. Three illuminance measurements were done with a luximeter, one with natural light and two at nightfall (with and without shadows). By studying their illuminance and luminance levels, it was perceivable the existence of lighting problems in all workplaces studied. Proven the inefficient lightning system, two experiments were run for the six workplaces. To the seventh section, as it is different from the others, a different approach was used. The results showed that with an implementation of roller shutters, 14 luminaires were enough to guarantee the necessary illuminance level. Without Dundee Roller Shutters, the number of luminaires needed was 15. To the seventh section it is recommended the utilization of a local lamp. The importance of lighting conditions is discussed, and the results obtained from illuminance measurements are presented so that improvements in the production area can be implemented.

Keywords Ergonomics · Illuminance · Luminance · Granite manufacturing

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1 Introduction

As human performance is directly related to profitability in the industrial environment, employees are essential in an organization [1]. There are numerous factors that can influence the working environment, such as, noise, lighting and others, that can be studied in terms of their effects on workers satisfaction, performance, health and safety [2].

Concerning the light, it is generally known that it can affect physical and psychological behaviors of humans [3]. Improving lighting in the workplaces, a positive effect is caused on the performance of the workers [1]. An excess or lack of light in the workstation can be responsible for eye-strain, fatigue, headaches, stress and accidents [4].

A lighting improvement in the industrial workplace can be introduced through changing the artificial lighting [1]. The illumination of this company during the day is sustained by daylight, so the lighting system is only lit when it gets dark on evening, which means that workers spend about 2 h in this situation. In this part of the day, insufficient lighting and incorrect design of lights may affect workers' wellbeing, as well as their productivity.

In the case study, it will be approached the importance of the lighting conditions in a granite factory. By the measurement of the illuminance levels at the workplaces, this study aims to investigate the present lighting conditions and to present recommendations on how to achieve improvements and guarantee the workers' comfort and safety.

2 Methodology

2.1 Occupational Conditions and Workers

In the granite company, the main activity is the transformation of granite into a diversity of products, such as grills, statues, cubes, etc. The company has two distinctive areas: saws section, where the stone is cut off, and the production area, where the stone, already cut off, is transformed on specific products. There are seven workers in the production area, all from the masculine gender, and with ages ranging from 20 to 43 years old. This manuscript will focus on the second area, once it is considered (by the company administration) the one that has a higher necessity of a good lighting system, since embed activities, such as: handling, holding on grinders and measurements are set there. Although there are not any walls in this area, the division of the workplaces is defined, and each work has a specific section. There are seven sections (Fig. 1) in the entire production area with a unique general lighting

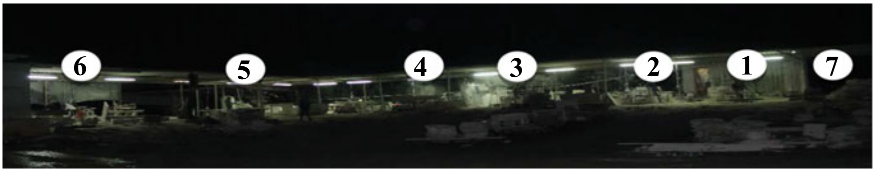

Fig. 1 The seven sections of the production area

system. However, six of them are lit by 13 fluorescent tubes, and one section by a LED spotlight. At the last section, the luminaire is too far from the workstation, and as it is separated from the others, it will be analyzed separately.

2.2 Data Collection

A questionnaire was developed to collect the employees' opinion about the lighting level at their workplaces (across the seven sections mentioned before). The anonymity was guaranteed and, based on literature review, 12 questions were elaborated concerning the following four effects of the environmental factors: employee satisfaction, perceived job performance, health and safety [2]. The questionnaire was divided in two parts: perception of the light during the day and during the nightfall, but most questions are focused on the second part. A descriptive statistical analysis was carried out using the results.

The workplaces' lighting assessment was divided into two phases. In the first one, the illuminance at the center of the work plane in each workstation was measured, with the existence of merely natural lighting. The second stage of the study took place around 5.30 p.m., when the daylight was inexistent, and the workers used artificial lighting to do their job. The artificial lighting come from luminaires equipped with fluorescents lamps that provide white light, located at the top of the workplace. At section seven, the lighting come from a spotlight equipped with a LED lamp, located laterally. This workplace is placed far from the others and does not receive any light from the other workplaces. To analyze the illuminance of the second stage, two measurements were made due to the existence of shadows. At the first, a measurement was done in the field of vision without the presence of any shadows, and in the second one it was considered, for measurement, the presence of shadows in the work plane, created by the positions that the workers needed to adopt in order to perform their job.

In all stages, the measurements were carried out with a luximeter, the data logger Delta Ohm model HD 9221. It allows evaluating if the level of light at the workplaces is sufficient or not. The minimum required illumination level for the proper task execution should be consulted at the ISO 8995:2002-Lighting of indoor workplaces. Afterwards, the DIALux Software was used to evaluate the present lighting on the production area and to explore alternatives to improve the workplace.

2.3 Lumen Method

In order to determinate the number of lamps necessary to guarantee an adequate lighting system the lumen method was used. This method is only applied to areas with at least one wall. It is used to determine the number of luminaires for a specific lighting level required, and it is obtained by the expression (1).

$$N = (E \times A)/(F \times U \times MD) \tag{1}$$

Where, N is the number of lamps, E is the required illuminance in Lux; F is the initial total lamp light output for each luminaire, U is the utilization factor, MD is the maintenance factor and A is the area of the working plane in square meters [5].

The factor E value is consulted at the ISO 8995:2002. The utilization factor (U) relates to the reflectance of the walls and ceiling, the room index and the type of luminaire used into a single value [5]. The room index is obtained through the expression (2) and describes a ratio between the area of the horizontal surfaces and the vertical surfaces.

$$Room\,Index = \ (L \times W)/(H(L + W)) \tag{2}$$

L is the length (in meters), W is the Width (in meters) and H is the Height of light fitting above the working plane (in meters). The maintenance factor (MD) is based on how often the lights are cleaned and replaced. This factor takes into account the age of the lamp, the accumulation of dust and deterioration of the luminaires, once all these factors reduce the lamp light output [5]. For normal conditions a factor of 0.8 should be used, to air-conditioned room a factor of 0.9, and in case of industrial environments a factor of 0.5 is adequate.

3 Results and Discussion

3.1 Questionnaire

The questionnaire was applied to the seven workers during a work break. The purpose and structure were explained to them. One of the questionnaires applied was excluded because it was incomplete (missing four answers). For the analysis of the results, five meaningful categories of questions were defined, represented in Fig. 2 where the respective answers that most workers chose were also mentioned.

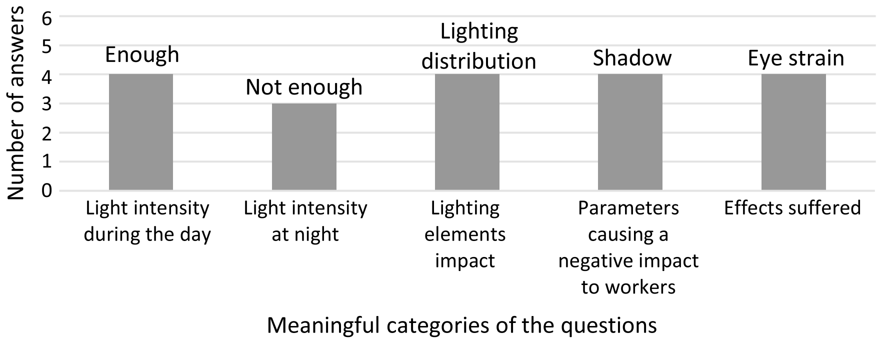

Fig. 2 Summary of the questionnaire results

3.2 *Illuminance Measurements*

For the understanding of the level of lighting conditions at workplaces, the value of the minimum required illumination level for the good task execution was consulted at the ISO 8995:2002. The activity studied is not listed at ISO: "Schedule of lighting requirements". Therefore, the values from an activity similar to the one studied were adopted: "Wood working & Furniture industry- work on wood working machines e.g. turning, fluting, dressing, rebating, grooving, cutting, sawing, sinking", thus the reference value is 500 lx.

The results of the illuminance measurements in production area is shown in Table 1.

The results demonstrated that the illuminance at workplaces 2, 5 and 7 is below the recommended value when the workers perform their task only with natural lighting.

When night falls and artificial lighting is used, the illuminance values are very low: between 110 and 245 lx, not considering the presence of shadows. This means that in all workplaces the illuminance checked is lower than the illuminance required. Considering the shadow formation, the illuminance values are below 25 lx except in workplace number two. These results show that the performance and comfort of workers can be negatively affected, as demonstrated by Juslén & Tenner [1].

Table 1 Illuminance measurements (lx)

Workplace		1	2	3	4	5	6	7
Day		537	494	501	506	424	614	150
Night	Without shadows	145	191	110	130	160	245	–
	With shadows	8.5	150	20.5	25	10	9	5.1

3.3 Workplace 7

The workplace 7 is isolated, the ceiling is higher and requires a machine that by itself creates a shadow. As stated in Table 2, the light is insufficient during the day and at night. For this workplace, a local light is recommended. The required illumination for this type of work has the value of 300 lx (adapted from the wood working to saw frame activity, obtained by ISO 8995:2002). This workstation can be considered of only 1 m^2, therefore the luminous flux should have a minimum value of 300 lm, making up a minimum potency of 6 W to the local light, considering an efficiency of 50%. For this calculation, it was assumed that the correct type of light that could be used is LED (Light Emitting Diode), because it is more efficient than others and provides the minimum energy loss [6]. This recommendation was also considered based on DIALux, and all the results proved that a local 6 W light was sufficient.

3.4 Study of Different Corrective Measures

Having the present situation understood, two scenarios were created so that improvements in the lighting level could be achieved.

3.4.1 New Distribution of Luminaires

Using the DIALux software, two different options were tested: with 14 and 15 luminaires positioned in a new distribution. The results are represented in Table 2,

Table 2 Results obtained from the simulations

Workplace	Illustrative area	14 luminaires	15 luminaires
6	A1	467	684
Actual extinct workplace	A2	482	707
Transition zone	A3	215	243
5	A4	596	600
Storage zone	A21	266	269
4	A8	638	639
3	A9	578	582
Assembly	A10	373	370
2	A11	613	614
1	A12	615	615
Storage zone	A14	127	127
7	A15	400	399

and it is stated that with 14 luminaires the values of illuminance are not sufficient (A1 and A2). However, the utilization of 15 luminaires provided all the workplaces the illuminance needed, according to ISO 8995:2002.

For the workplaces 1–7 it was already explained the required illuminance, but the transition zones, storage zones as well as the assembly area have a different value. The transition zone needs a minimum value of illuminance of 100 lx (adapted from the general building areas to circulation areas and corridors, obtained by ISO 8995:2002). In the same document, it was possible to conclude that the required illuminance for the storage zone is 200 lx (adapted from the general building areas to store, stockrooms, cold store activity) because these sections are continuously occupied. The assembly section (A10) has a minimum value of illuminance of 300 lx that was adapted from the same activity chosen in the workplace mentioned before.

3.4.2 Dundee Roller Shutters and a New Distribution of Luminaires

The actual production area is constituted only by a ceiling, but in this scenario the authors considered the presence of a building behind the workplaces and a side wall between the first and last workplace. This hypothesis aims to reduce the light loss and take advantage of the light reflection. Firstly, it is necessary to know how many lamps are necessary to an entire production area, using Lumen Method. The workplace number 7 is not considered, since this workstation has a high height.

Once again, the E factor is the reference value for the required illumination: 500 lx (ISO 8995:2002). After that, the utilization factor (U) is calculated. For that, it is necessary to identify the room index, the reflectance of the roller shutters and ceiling. Where L = 24 m, W = 3 m, H = 2.2 m:

$$\mathit{Room\,Index} = (24 \times 3)/(2.2(24 + 3) = 1.21 \tag{3}$$

The material of the roller shutters and the ceiling is sheet metal (grey), so the reflectance value is 0.70 [7].

According to the room index value, one table was accessed [7] and then with an interpolation the value for the utilization factor of 52.2% was obtained.

For an industrial atmosphere where cleaning is difficult, like in the sections studied, a maintenance factor with a value of 0.5 is used. The parameter F was obtained (5200 Im) knowing that the type of lamp used by the company is a T8 Polylux–fluorescent linear tri-phosphor. The working area (A) is 72 m^2. The calculation of the number of lamps is now possible:

$$N = (500 \times 72)/(5200 \times 0.522 \times 0.5) = 26\ \mathit{lamps} \tag{4}$$

The minimum value of the luminous flux is calculated, by the following expression:

Table 3 Results obtained from the simulation

Workplace	Illustrative area	14 luminaires with roller shutters
6	A1	543
Actual extinct workplace	A2	555
Transition zone	A3	237
5	A4	668
Storage zone	A21	326
4	A8	694
3	A9	628
Assembly	A10	419
2	A11	651
1	A12	616
Storage zone	A14	140
7	A15	300

$$\Phi = (500 \times 72)/(0.522 \times 0.5) = 137{,}932\,\text{lm} \tag{5}$$

In the present industry, each luminaire is constituted by 2 lamps, which means that the ideal number of luminaires is 13. However, $26 \times 5200 = 135{,}200$ lm is lower than the 137,932 lm necessary, so one more luminaire must be implemented, thus guaranteeing the necessary luminous flux. Using 14 luminaires and a new distribution, a new scenario was tested using the DIALux software obtaining the illuminance values sufficient in every station (Table 3).

3.4.3 Comparison Between the Two Scenarios Tested

Using the DIALux software, with a new distribution of luminaires it is possible to conclude that 15 luminaires ensure sufficient illuminance. In the second experiment, using the lumen method, the existence of roller shutters and a new distribution for the 14 luminaires proved to be a viable option. So, these two scenarios have proven to guarantee the necessary levels of illuminance according to ISO 8995:2002. Due to the viability of both scenarios, the organization should choose the one which matches the most with its own criteria.

4 Conclusion

Many field studies where the lighting change in industrial environment was carried out, demonstrate that this change may increase the output of the workers [1]. In this study, the lighting level was measured and changes in the illuminance level are crucial. To assess the workers' wellbeing, a questionnaire about the lighting conditions existent was taken and the results showed that workers believe that good lighting impacts on their work. The presence of shadows is unanimous, so it is necessary to change their position for a better view. The measurement of the illuminance allowed to confirm that the present lightning system does not guarantee the minimum levels required. Seeking improvements to this company, two experiments were studied. It was concluded that with 15 luminaires and a new distribution for those luminaires the illuminance is sufficient. Besides that, if the existence of roller shutters with a new distribution for the 14 luminaires is considered, it is also a viable option. For the workplace 7 a local lamp is highly recommended.

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Part V
Psychosocial Issues

Psychosocial Risks Factors Among Psychologists: What Are We Talking About?

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Abstract Mental health professionals, as psychologists, have a demanding and emotionally exhausting profession, which makes it susceptible to occupational risks, namely psychosocial risks. Three areas of psychology practice, Clinical and Health Psychology, Work and Organizational Psychology, and Education Psychology are expose to different working contexts. The purpose of this study was to evaluate psychosocial risks factors and their differences between the three psychology specialties. 339 psychologists participated in the study and results suggest significant differences in terms of high demands and work intensity, working hours, work and employment relations, ethical and values conflicts and work characteristics. In conclusion, this study allows a better understanding to provide strategies for preventing and reducing the incidence of psychosocial risks among psychologists.

Keywords Psychosocial risk factors · Work activity · Psychologists

1 Introduction

For mental health professionals, specifically psychologists, caring for those who are emotionally stressed or distressed is often itself stressful. Several researchers have amply demonstrated that significant levels of burnout exist in the helping professions, concretely in psychologists [1]. Burnout has been defined as a syndrome of emotional exhaustion, depersonalization, and reduced personal accomplishment

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characterized by cynicism, psychological distress, feelings of dissatisfaction, impaired interpersonal functioning, emotional numbing, and physiological problems [2]. Burnout's etiology is not significantly associated with worker reactions to traumatic client material but is associated with other workplace characteristics, such as caseload size and institutional stress [3]. Other studies also indicated that psychologists that are therapists commonly experience "compassion fatigue" [4, 5]. Compassion fatigue consists of negative behaviors and emotions that often occur in response to helping someone else who has experienced a traumatic event [4].

In an early study of burnout, Ackerley et al. [6] examined levels of burnout for doctoral-level psychologists, primarily employed in private practice, and found that 39.9% of the psychologists were experiencing high levels of emotional exhaustion and 34.3% reported depersonalizing their clients. Other studies have examined burnout in school psychologists [7, 8].

Factors related to the individual psychologists' characteristics, such as age [9], and years of experience [10], or having a prior personal experience with trauma also has been related to psychologists' compassion fatigue [11, 12]. Nerveless conditions in the workplace, such as greater amounts of secondary exposure to traumatized clients (amount of time spent working with traumatized clients in direct care), higher percentage of individuals with PTSD on a counsellor's caseload, and greater length of time spent providing treatment (long work hours), have been shown to increase the risk of compassion fatigue [3, 10, 13, 14]. Psychosocial risks factors are related to the way work is conceived, organized and managed, as well as the social work context. Psychosocial risks including high demands and intensity of work, emotional demands, lack of autonomy, poor social relations, ethical and values conflicts in the workplace [15, 16]. In the psychology practice, lack of workplace support, less control over work activities, and over-involvement with clients have been associated with burnout [6, 17]. In fact, mental health and occupational psychosocial risks have been recognized as priorities in health and safety in the European Union for at least two decades [18–20]. The epidemiological literature gives us convincing data on the effects of psychosocial health risks, including mental health problems (anxiety and depression). Psychosocial risks factors among psychologists seems to be an important cause of mental health distress [16]. It is therefore necessary to take a perspective of assessing their origin, that is, psychosocial risk factors (rather than psychosocial risks) that may cause disruption to physical and social mental health [15]. Indeed, psychosocial risk factors, related to content, nature, work organization and social relations of work—less obvious and whose effects are manifested more differently—should be integrated into the assessment of the impact of work on health and on well-being.

Given the paucity of research on burnout and compassion fatigue in psychologists, continued research seems warranted. The purpose of this study was to evaluate psychosocial risks factors and their differences between the three psychology specialties: Clinical and Health Psychology, Work and Organizational Psychology, and Edu-cation Psychology.

2 Methods

2.1 Study Design and Ethics

A cross sectional study was conducted in Portuguese's psychologists. The Ethics Committee of the Fernando Pessoa University, Porto, approved the research project, within the standards required of Helsinki Declaration. Psychologists were recruited through the snowball method and data collection was conducted for those who gave informed consent to participate in this research, according to their availability. Participation was voluntary, and confidentiality and anonymity were guaranteed. The instruments were handed out together with a response envelope in which to return the questionnaire to the researchers.

2.2 Participants

A sample with 339 Portuguese aged between 22 and 58 years (M = 36.44; SD = 7.33) made part of this study. The most representative age group was between 30 and 39 years old (46.4%), with 78.5% female, and 21.5% male. Most of the participants are from the North of Portugal (96%) and represent three areas of expertise, working at different places such as hospitals, healthcare centers (public and private), high schools, and private companies. The participants have different years of experience, from those who have only one year of practice to others with 35 years of practice. 78% of the participants have permanent employment contracts, and 22% are working as freelancers. More than half of psychologists work full-time (72%) (Table 1).

Table 1 Socio-demographic characteristics

Socio-demographic characteristics		Total sample (%)
Gender	Men	21.5
	Women	78.5
Education	Bachelor's degree	38.9
	Master's degree	58.4
	PhD	2.7
Age	20–29 years old	20.5
	30–39 years old	46.4
	40–49 years old	28.9
	50–59 years old	4.2
Specialty areas	Clinical and Health Psychology (CHP)	58.2
	Work and Organizational Psychology (WOP)	21.3
	Education Psychology (EP)	20.5

2.3 Instruments

This study was supported by the Health and Work survey—INSAT [21–23], which includes a subscale that assesses psychosocial risk factors at work

The INSAT Survey is an organized self-assessment questionnaire that assesses working conditions, health and well-being, and the relationship between them. Seven axes structure this survey, most of which include Likert scales: (I) Labor; (II) Working conditions and risk factors; (III) Living conditions outside work; (IV) Training and work; (V) Health and work; (VI) My health and my work; and (VII) My health and my well-being. Regarding the purpose of this study, the subscale of psychosocial work factors was used: work rhythm and intensity; Working hours; lack of autonomy; working relationships with co-workers; employment relations with the organization; emotional demands; ethical and values conflicts; and work characteristics. The INSAT was validated for the Portuguese population through the Rasch and Partial Credit Model (PCM) and obtained a value considered very good (>0.8) [24].

2.4 Statistical Analysis

The SPSS for Windows, version 22.0 was applied to perform the statistical analysis. The significance level adopted was $p \leq 0.05$. Frequency and percentage analysis were performed on the demographic characteristics of the participants (categorical variables of the INSAT questionnaire—psychosocial factors). Kruskal-Wallis tests were performed to analyze the differences between the three specialty areas of psychologists practice. Pair comparison, using Dunn's pairwise tests, was also performed to analyze differences between each two groups.

3 Results

3.1 Descriptive Analysis

The characterization of psychosocial work factors ("yes" answers) that have a significant impact on the professional practice of psychologists are presented in Table 2.

Table 2 Characterization of psychosocial work factors

Psychosocial risk factors	Sample (n = 339)
High demands and work intensity (α = 0.828)[a]	(%) Yes
Intense work pace	59.5
Dependent on colleagues to do my work	30.2
Dependent on direct clients' requests	52.5
Have to follow production norms or meet strict deadlines	44.8
Have to adapt permanently to changes in methods or instruments	38.0
Not being told clearly what to do	29.0
Have to deal with contradictory instructions	32.3
Exposed to frequent disruptive interruptions	36.3
Always changing roles and tasks depending on the needs of the organization	28.3
Exposed to highly demanding situations	55.8
Working hours (α = 0.766)[a]	
Have to continue working beyond my assigned timetable	60.8
Have to work at home beyond my schedule	64.2
Have to "skip" or shorten a meal or not have a break	39.4
Have to maintain permanent availability at any time of the day	38.0
Lack of autonomy (α = 0.757)[a]	
Have no freedom to decide how to do work	16.4
Not be able to participate in decisions concerning my work	8.3
Work relations with coworkers and managers (α = 0.767)[a]	
Need help from colleagues and not have	30.6
It is rare to exchange experiences with other colleagues to better performed the work	12.7
Not having my opinion taken into consideration for the functioning of the department	6.3
Impossible to express myself	9.5
Not having recognition by colleagues	13.0
Have no one I can trust	15.9
Employment relations with the organization (α = 0.776)[a]	
Threat of job loss	42.8
Career progress is almost impossible	38.5
Remuneration does not allow me to have a satisfactory standard of living	22.7
Lack the means to carry out my work	6.3
Emotional demands (α = 0.847)[a]	
Direct contact with the public	78.4
Have to endure the demands of the public	76.7
Have to deal with situations of tension in the relations with the public	76.9
Being exposed to the suffering of the others	84.7
Have to simulate good mood and/or empathy	74.1
Have to hide my emotions	72.8

(continued)

Table 2 (continued)

Psychosocial risk factors	Sample (n = 339)
Ethical and values conflicts (α = 0.700)[a]	
Have to do things I disapprove	19.5
Lack the means to do a job well done	26.0
Work characteristics (α = 0.723)[a]	
Lonely work	31.0
Varied work	79.2
Unpredictable work	69.2
Complex work	80.7
Stimulating work	90.6
Continuous learning work	91.2

[a]Cronbach's alpha

3.2 Inferential Analysis

In order to accomplish the second objective, an inferential analysis of the psychosocial risk factors, using Kruskal-Wallis test, was made in order to analyze the differences between the three areas of psychology practice (only for $p < 0.05$) (Table 3).

As presented in Table 3 there are significant differences between the three areas of psychology practice, being more pronounced in psychosocial risk factors such as "Dependent on colleagues to do my work", "Have to work at home beyond my schedule", "Have to skip or shorten a meal or not have a break", "Have to maintain permanent availability at any time of the day", "Direct contact", "My professional conscience is shaken", "Monotonous work" and "Boring work" ($p < 0.005$).

Pairwise comparison was also performed to analyze differences between the three areas of psychology practice (only for $p < 0.05$) (Table 4).

Table 4 shows significant differences between pairs Education Psychology—Work Organizational Psychology (EP-WOP), Education Psychology—Clinical and Health Psychology (EP-CHP) and Work Organizational Psychology—Clinical and Health Psychology (WOP-CHP).

A strong evidence ($p < 0.005$) of a difference between pairs were found for psychosocial risk factors such as "Dependent on colleagues to do my work" for pair EP-CHP, all "Working hours" psychosocial risk factors for pair WOP-CHP, for "My professional conscience is shaken" for pair WOP-CHP, for "Monotonous work" for pairs EP-WOP and EP-CHP, and finally for "Boring work" for pair EP-CHP.

Table 3 Differences between the three areas of psychology practice

Psychosocial risk factors	Kruskal-Wallis	
High demands and work intensity	$\chi^{2\ (G.L.=2)}$	***p***
Dependent on colleagues to do my work	11.178	0.004
Maintain eye contact	7.874	0.020
Working hours		
Have to work at home beyond my schedule	12.884	0.002
Have to sleep at unusual hours	9.021	0.011
Have to "skip" or shorten a meal or not have a break	13.039	0.001
Have to maintain permanent availability at any time of the day	11.377	0.003
Work relations with coworkers and managers		
Rare to exchange experiences with other colleagues	6.071	0.017
Not having recognition by colleagues	8.179	0.048
Employment relations with the organization		
Career progress is almost impossible	7.823	0.020
Remuneration does not allow me to have a satisfactory standard of living	6.041	0.049
Emotional demands		
Direct contact	11.926	0.003
Have to deal with situations of tension in the relations	9.467	0.009
Being exposed to the risk of verbal aggression	8.161	0.017
Ethical and values conflicts		
Have to do things I disapprove	6.026	0.049
My professional conscience is shaken	16.965	0.000
Work characteristics		
Lonely work	9.619	0.008
Monotonous work	12.916	0.002
Boring work	11.048	0.004

Table 4 Pairwise differences between the three areas of psychology practice

Psychosocial risk factors	Average Rank			Differences between Pairs ($p < 0.05$)		
	EP	CHP	WOP	EP-WOP	EP-CHP	WOP-CHP
High demands and work intensity						
Dependent on colleagues to do my work	126.96	166.65	165.17	✓ (0.025)	✓ (0.004)	
Maintain eye contact	150.77	172.48	154.77		✓ (0.045)	
Working hours						
Have to work at home beyond my schedule	157.88	179.31	134.45			✓ (0.001)
Have to sleep at unusual hours	167.84	171.01	144.40			✓ (0.009)

(continued)

Table 4 (continued)

Psychosocial risk factors	Average Rank			Differences between Pairs ($p < 0.05$)		
	EP	CHP	WOP	EP-WOP	EP-CHP	WOP-CHP
Have to "skip" or shorten a meal or not have a break	168.70	168.89	129.68	✓ (0.013)		✓ (0.002)
Have to maintain permanent availability at any time of the day	150.83	170.59	134.44			✓ (0.003)
Work relations with coworkers and managers						
Not having recognition by colleagues	152.78	165.01	147.92			✓ (0.027)
Employment relations with the organization						
Career progress is almost impossible	176.80	161.00	137.90	✓ (0.018)		
Remuneration does not allow me to have a satisfactory standard of living	156.31	170.06	142.85			✓ (0.049)
Emotional demands						
Direct contact	129.69	160.58	167.11	✓ (0.005)	✓ (0.007)	
Have to deal with situations of tension in the relations	137.39	162.21	185.57	✓ (0.006)		
Being exposed to the risk of verbal aggression	135.72	166.39	176.16	✓ (0.021)	✓ (0.046)	
Ethical and values conflicts						
Have to do things I disapprove	153.54	165.24	180.89	✓ (0.044)		
My professional conscience is shaken	162.41	160.93	192.40	✓ (0.005)		✓ (0.000)
Work characteristics						
Lonely work	172.53	171.11	139.25	✓ (0.035)		✓ (0.009)
Monotonous work	179.33	155.13	151.18	✓ (0.004)	✓ (0.003)	
Boring work	186.46	161.96	173.89		✓ (0.004)	

4 Discussion

The results of this study indicated there are significant differences between the three areas of psychology practice, being more pronounced in psychosocial risk factors such as high risk of "Dependent on colleagues to do my work", "Have to work at home beyond my schedule", "Have to skip or shorten a meal or not have a break", "Have to maintain permanent availability at any time of the day", "Direct contact with the public", "My professional conscience is shaken", "Monotonous work" and "Boring work". These findings are supported by previous research that associated psychologist's burnout and compassion fatigue with workplace characteristics [3–5].

In general, psychologists with clinical and health practice have a higher degree of risk in the different psychosocial work factors concretely high demands and work intensity (e.g. dependent on colleagues to do my work) and working hours (e.g. have to work at home beyond my schedule, have to skip or shorten a meal or not have a break, have to maintain permanent availability at any time of the day). These results are in accordance with other studies that underlies the impact of conditions in the workplace, such as greater length of time spent providing treatment (long work hours) [3, 10, 13, 14]. Also, previous research has indicated lack of workplace support, less control over work activities, and over-involvement with clients have been associated with burnout [6, 17].

For work and organizational psychologists, we found higher levels of psychosocial risk factors for emotional demands (e.g. Direct contact with the public), which seems to be in accordance with the role of organizational mediators and moderators [25]. Working as a psychologist in an organization is a tricky balance between the different stakeholders' characteristics, which involves the understanding of the different perspectives. This request often reflects a hard and demanding expectation that the intermediation will contribute to react more positively to the "work demands" [16]. The psychological practice seems to imply a permanent conflict management and the hard demand of have to deal with situations of tension in the relations that can induce ethical and values conflicts in work and organizational psychologists. Have to do things that I disapprove and have the feeling that my professional conscience is shaken lead to an alarming situation, less visible, but with a great impact on health and well-being [26]. Indeed, a high level of value conflicts affected negatively job satisfaction and commitment and relation person-organization fit [27].

Educational Psychologists seems to be more sensitive to psychosocial risk factors related to the work characteristics like monotony or boredom work. The way work is conceived, organized and managed, as well as the economic and social context of work can have a huge impact on the health and well-being. In fact, in the context of school structure characterized by bureaucratic work structures, the practice of psychology is more organized by rigid procedures, and the use of technology to routinize working practices [28, 29]. The impact of these psychosocial work factors induce a lower worker flexibility, quality and an innovation, and can be associate with feelings of apathy and depression [30, 31]. These results highlight the importance of assessing the psychosocial risk factors and the need to define the best practices of prevention and intervention in a profession aimed at promoting the well-being of people.

5 Conclusions

This study focused on psychosocial risks among psychologists according to their different specialties. Other studies have focused on the phenomena of compassion fatigue and burnout in the helping professions. Our results give important information about psychologist's work conditions that suggests possible interventions to improve it in different areas of psychology. Study limitations should be noted. Our survey methodology required us to limit the number of items we could include, so potentially significant variables (e.g., habitual coping approaches, personal trauma history, exposure to trauma type, and frequency and quality of clinical supervision) were not included in the instrument. While we were able to use a sampling frame of the Portuguese licensed psychologists, we were unable to sample a representative sample of all country, only from the North of Portugal. In conclusion, we can summarize that psychologists are exposited to several psychosocial risk's factors in the workplace.

Continued research on the experience and correlates of these factors is critical to developing better understanding and improved strategies for preventing and reducing its incidence among psychologists and other human service providers. Such research among psychologists and other mental health professionals is directly relevant to their health and well-being, and indirectly relevant to the quality of care they provide to their client.

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Stress and Work Engagement in Health Professionals

Liliana Fontes, Alice Gonçalves, A. Rui Gomes and Clara Simães

Abstract Occupational stress can produce negative consequences on workers' mental and physical health, which affect them and their organization. Work engagement, on the other hand, is linked with positive affective-motivational states of realization related to work, and negatively correlates with fatigue, anxiety, and depression. Thus, this study aimed to analyse the relationships between stress and engagement in health professionals working in a hospital in the North of Portugal. A convenience sample of 221 health professionals participated in this cross-sectional study and answered two instruments to assess stress and engagement at work. Results showed that stress dimensions predicted the three dimensions of engagement. Specifically, health professionals with no intention to change services, those with more stress dealing with clients, and who worked only at the hospital showed higher overall engagement. Conversely, participants who reported more stress in their relationships at work and in leading training activities presented with less work engagement. Therefore, these findings contribute to increase the knowledge of health professional's mental conditions and can be used to implement interventions to mitigate the effects of stress on these professionals and increase their levels of work engagement.

Keywords Occupational stress · Work engagement · Health professionals

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1 Introduction

Stress can be defined as the relationship between the burden felt by the person and the psychophysical responses it elicits [1]. It occurs when environmental demands surpass the person's capacity to adapt, leading to a negative impact on the person's health. Occupational settings, like hospitals, are one context in which long-term stress is likely to occur. Here, stress produces negative consequences on workers' physical and mental health, and in their work satisfaction and engagement, affecting the individual and the organization [2]. Research with health professionals shows a high incidence of occupational stress related to work overload; shift irregularity and night shifts; high number of patients; ambiguity and role conflict; high responsibility for patients' lives; lack of autonomy; and the need to deal with constant suffering, pain, and death [3, 4].

Work engagement is a psychological presence where people are in full contact with their work and with people in their work environment [5]. Engagement is a positive affective-motivational state of realization related to work characterized by the dimensions vigour, dedication, and absorption [6]. Vigour describes people with high levels of energy and resilience, a will to invest effort in work, resistance to fatigue, and persistence when faced with obstacles. Dedication regards displaying high personal involvement with work, feelings of enthusiasm, meaning, pride, inspiration, and challenge. Absorption is a pleasant state of concentration and immersion in work, time flies, and the person has trouble disengaging [6]. Thus, work engagement includes an energetic (vigour), emotional (dedication), and cognitive (absorption) dimension [7].

Engagement at work is a source of personal development positively and significantly associated with psychological empowerment, job and life satisfaction, and negatively correlated with fatigue, anxiety, and depression [8, 9]. Some factors that facilitate it are: social support, work performance, personal resources, self-efficacy and self-esteem, positive psychological capital, beliefs, optimism, resilience, resources, and organizational requirements [6, 9]. The concept predicts good job performance and customer satisfaction, and resilience and occupational resources can facilitate engagement at work, which can modulate the effects of organizational resources on work performance, well-being, and quality of life [11].

Engaged workers show better physical and psychological health, create their own resources, work with more effort (vigour), are immersed in their activities (dedication), and fully focused on their tasks (absorption) [10]. They are an asset to themselves, colleagues, and organizations, less counter-productive, show better performance and productivity, lower turnover and absenteeism, and are more successful [7].

In sum, work engagement promotes individual and organizational benefits. Thus, this study aims to analyse which stress dimensions predict work engagement.

2 Methods

2.1 Design

Quantitative cross-sectional study, exploratory, descriptive, and correlational.

2.2 Participants

The study included a convenience sample of 221 health professionals (20.4% doctors and 79.6% nurses) working in several medical specialties, from a hospital in the northern region of Portugal. Participants' ages varied between 22 and 65 years old (M = 37.73; SD = 9.15) and the majority were female (76.6%). Most participants were married (59.7%) with children (62.4%). The vast majority worked full-time exclusively at the hospital (74.2%). Finally, most engaged in some form of physical activity (51.2%), as well as having a hobby (47.5%). All participants were informed about the nature and objectives of the study and signed informed consent forms to ensure their voluntary participation. The evaluation protocol was delivered to each hospital unit/service. Each participant was instructed to fill out the questionnaires and deliver them to the researcher in a sealed envelope, to ensure participants' anonymity. Thus every procedure followed all ethical principles outlined in the Declaration of Helsinki, and the study was submitted to and approved by the Ethics Committee of the hospital where the data collection took place.

2.3 Measures

The evaluation protocol included a Sociodemographic and Professional Questionnaire and the following instruments of psychological assessment:

Stress in Health Professionals Questionnaire (SHPQ [12]). Evaluates levels and sources of stress at work in six dimensions: working with clients (related to the responsibility of providing services to their clients), work overload (stress of the professionals related to workload and the number of hours of service to be done), career progression and salary (stress of health professionals related with the opportunities of career development and salary received), relationships at work (stress of health professionals related to the work environment as well as the relationships maintained with colleagues and hierarchical superiors), leading training activities (stress of health professionals related to situations where they develop and conduct training activities and make public presentations), and work-home interface (stress of health professionals related to work demands that interfere with family relationships and with the support received from significant others). Higher scores indicate higher perception of stress in each domain, pointing to potential sources of stress at work.

Utrecht Work Engagement Scale (UWES [13]; Portuguese version [14]). Evaluates work engagement in three dimensions: vigour (refers to high levels of energy and mental resilience while working, the willingness to invest effort in one's work, and persistence in the face of difficulties); dedication (refers to being involved and finding meaning in one's work, being challenged, and experiencing a sense of enthusiasm, inspiration, and pride); and absorption (refers to being fully concentrated and engrossed in one's work, whereby time passes quickly and one has difficulties detaching from work). Higher scores in each dimension indicate, respectively, a greater willingness to persevere in the face of obstacles in the workplace, or when confronted with a challenge; that individuals see their work as meaningful and inspiring; and that individuals report being happily engrossed and concentrated while working.

3 Results

Parametric tests were performed after ensuring that all corollaries were met. Confidence intervals were defined at 95%, with an alpha level of .05 as the threshold for significance. Results were obtained through univariate and multivariate analyses of variance, using IBM SPSS (25). Namely, to study the independent effect of stress dimensions on engagement, a hierarchical regression analysis was performed. To do so, we considered three blocks of variables, entered as follows: step (1) sociodemographic variables; step (2) professional variables; and step (3) stress variables.

3.1 Descriptive Statistics

Overall, 38.9% of health professionals reported a moderate level of stress and 56.1% described their professional activity as very stressful, as measured by the SHPQ. The stress dimensions that contributed the most to these results were work overload, career progression and salary, dealing with clients, and relationships at work. "Formal" aspects of work (work overload and career progression and salary) seem to produce higher stress in these participants than "relational" aspects of work that appeared as the third and fourth sources of stress (dealing with clients and relationships at work).

Assuming a cut-off point of 4 on the UWES scoring, only 26.9% of participants showed high engagement levels. Specifically, dedication was the highest scored dimension at 55.7%, followed by vigour (42.5%), and absorption (35.7%).

3.2 Predicting Dedication

The regression model in Table 1 significantly predicts dedication ($F = 8.953$, $p < .001$), explaining 32.6% of the total variance. Specifically, it shows that participants who do not have the intention to change services ($\beta = -.305$) and those reporting more stress related to dealing with clients ($\beta = .230$) showed more dedication to work. Additionally, health professionals reporting more stress with relationships at work ($\beta = -.245$) and in leading training activities ($\beta = -.139$) exhibited less dedication to work.

Table 1 Regression model for predicting dedication (N = 221)

Predictors for Dedication	$R^2(AdjR^2)$	$F(df)$	β	t	p
Step 1	.040 (.031)	4.381 (2, 212)			
Age (years)			−.021	−.162	.871
Having children[a]			−.112	−1.646	.101
Step 2	.271 (.246)	10.978 (7, 207)			
Contractual status[b]			.023	.343	.732
Place of work[c]			.086	1.427	.155
Changing hospitals[d]			−.094	−1.282	.201
Changing services[e]			−.305	−4.086	<.001
Professional Experience (years)			−.123	−.975	.331
Step 3	.367 (.326)	8.953 (13, 201)			
SQHP-Dealing with clients			.230	2.972	.003
SQHP-Relationships at work			−.245	−3.153	.002
SQHP-Career progression & salary			−.019	−.230	.818
SQHP-Work overload			−.075	−.894	.372
SQHP-Work-Home interface			−.054	−.656	.512
SQHP-Leading training activities			−.139	−1.993	.048

Note [a]Dichotomous *variable*: 0 = no, 1 = yes
[b]Dichotomous variable: 0 = precarious, 1 = non-precarious
[c]Dichotomous variable: 0 = hospital only, 1 = hospital and other
[d]Dichotomous variable: 0 = no, 1 = yes
[e]Dichotomous variable: 0 = no, 1 = yes

3.3 Predicting Absorption

The regression model in Table 2, testing for the independent effects of stress dimensions on absorption, is significant ($F = 7.081$, $p < .001$), and explained 25.4% of the total variance. Specifically, it shows that participants working only at the hospital ($\beta = .130$) and those with no intentions to change services ($\beta = -.265$) reported more absorption with work. In addition, those who present more absorption with work are health professionals that reported greater stress dealing with clients ($\beta = .207$) and those who reported less stress associated to relationships at work ($\beta = -.294$).

Table 2 Regression model for predicting absorption (N = 221)

Predictors for Absorption	$R^2(AdjR^2)$	$F(df)$	β	t	p
Step 1	.022 (.018)	4.818 (1, 213)			
Having children[a]			−.101	−1.523	.129
Step 2	.208 (.185)	9.104 (6, 208)			
Contractual status[b]			−.109	1.601	.111
Place of work[c]			.130	2.020	.045
Changing hospitals[d]			−.021	−.272	.786
Changing services[e]			−.265	−3.401	.001
Professional Experience (years)			.020	.307	.759
Step 3	.296 (.254)	7.081 (12, 202)			
SQHP-Dealing with clients			.207	2.544	.012
SQHP-Relationships at work			−.294	−3.610	<.001
SQHP-Career progression & salary			−.038	−.425	.671
SQHP-Work overload			−.017	−.201	.841
SQHP-Work-Home interface			−.036	−.419	.675
SQHP-Leading training activities			−.074	−1.022	.308

Note[a]Dichotomous variable: 0 = no, 1 = yes
[b]Dichotomous variable: 0 = precarious, 1 = non-precarious
[c]Dichotomous variable: 0 = hospital only, 1 = hospital and other
[d]Dichotomous variable: 0 = no, 1 = yes
[e]Dichotomous variable: 0 = no, 1 = yes

3.4 *Predicting Vigour*

The regression model shown in Table 3 significantly predicted vigour (F = 6.573, p < .001), explaining 22.3% of the total variance. Specifically, it shows that health professionals with children (β = −.173) and those with no intention to change services (β = −.244) report higher levels of vigour. Conversely, health professionals who presented less vigour are those that report higher levels of stress in their relationships at work (β = −.282) and in leading training activities (β = −.146).

4 Discussion

More engaged employees tend to have high energy levels, strongly identify with their occupational activities [10], and are more protected against the negative effects of occupational stress. It is thus crucial to better understand which stress domains can predict work engagement through dedication, absorption, and vigour.

Results showed that dedication was significantly predicted by stress, with professionals who report lower stress levels showing more dedication. The main

Table 3 Regression model for predicting vigour (N = 221)

Predictors for Absorption	$R^2(AdjR^2)$	$F(df)$	β	t	p
Step 1	.036 (.031)	7.850 (1, 213)			
Having children[a]			−.173	−2.555	.011
Step 2	.157 (.137)	7.798 (5, 209)			
Contractual status[b]			.034	.490	.625
Place of work[c]			.100	1.549	.123
Changing hospitals[d]			−.037	−.471	.638
Changing services[e]			−.244	−3.080	.002
Step 3	.263 (.223)	6.573 (11, 203)			
SQHP-Dealing with clients			.023	.276	.783
SQHP-Relationships at work			−.282	−3.398	.001
SQHP-Career progression & salary			.093	1.041	.299
SQHP-Work overload			−.040	−.450	.653
SQHP-Work-Home interface			−.035	−.397	.692
SQHP−Leading training activities			−.146	−1.961	.051

Note [a]Dichotomous variable: 0 = no, 1 = yes
[b]Dichotomous variable: 0 = precarious, 1 = non-precarious
[c]Dichotomous variable: 0 = hospital only, 1 = hospital and other
[d]Dichotomous variable: 0 = no, 1 = yes
[e]Dichotomous variable: 0 = no, 1 = yes

predictors of dedication were intention to change services, dealing with clients, relationships at work, and leading training activities. Thus, participants who do not intend to change services, deal more with clients, have less stress in work relationships, and do not lead training activities show greater dedication and engagement at work. Absorption was also predicted by stress, with higher levels of stress associated with less absorption. Specifically, participants with no intention of changing services and those who report less stressful relations at work exhibit higher absorption and thus, more engagement at work. Finally, regarding vigour, having children and having no intention to change services predicted higher levels of vigour, whereas higher levels of stress in relationships at work and in leading training activities predicted lower levels of vigour.

These results agree with studies that point to social support, work performance, personal resources, self-efficacy and self-esteem, positive psychological capital, beliefs, optimism, resilience, resources, and organizational requirements as variables that contribute to work engagement [7, 10]. Specifically, we found that higher levels of stress predict less engagement at work. Stress is strongly influenced by the majority of these factors, allowing us to posit that those with resources to deal with stress will exhibit higher work engagement, including dedication, absorption, and vigour.

Within this framework, it is crucial to ensure that health professionals attain high levels of work engagement in order to guarantee their quality of life at work and at home and, concomitantly, to protect them against the harmful effects of stress on their health, professional practice, and on the organizational system. Moreover, highly engaged professionals also benefit the organization, mainly by being more productive and keeping their clients satisfied [7, 10]. Keeping in mind the life and death nature of their work, it is our opinion that it is vital that stress levels are low to ensure professionals' high engagement and the high quality of the health care provided.

To target the variables that predict work engagement, management and government should cooperate with multidisciplinary teams to implement interventions aimed at these variables. Good practices are specific to each context [7, 15], but strategies to improve engagement include greater socialization and better evaluation of employees, establishing a psychological contract during staff selection, and increasing labour resources [7]. The most effective strategies are inherent to the organization. Consequently, it is the healthcare organization that must adapt and ensure it has strategies in place to promote its workers' health. Although some individual characteristics can help protect against stress, most strategies are the responsibility of the organization, as is evidenced by our results pertaining to, for example, stress in relationships at work: although it is possible to target this individually, by teaching strategies to manage stress, it appears more effective to attempt to change the overall work environment. Given the apparent protective quality of working with patients, which predicted both absorption and dedication, hospitals should ensure a balanced distribution of patients, guaranteeing that all health professionals have the opportunity of working with them and thus benefit from their protective quality.

Conversely, professionals with more stress in their relationships at work and who lead training activities showed less engagement. Thus, psychologists should be available to intervene, focusing on healthy work environments. Finally, they could implement training sessions to help health professionals with public presentations and to teach leadership skills invaluable to all sectors of their lives. Thus, health professionals would increase their engagement and concomitantly decrease stress levels.

In sum, health professionals' work engagement is influenced by stress. Therefore, hospitals should implement interventions that target occupational stress variables with an impact on the three domains of engagement—dedication, absorption, and vigour.

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Stress and Burnout in Health Professionals

Alice Gonçalves, Liliana Fontes, Clara Simães and A. Rui Gomes

Abstract Occupational stress and burnout are a global epidemic that can cause severe negative effects on workers' physical and emotional health. Health professionals working in a hospital setting are especially at risk, due to the inherent characteristics of their work. Consequently, this study aimed to analyse the relationships between stress and burnout in health professionals working in a hospital in the North of Portugal. A convenience sample of 221 health professionals participated in this cross-sectional study and answered two instruments to assess stress and burnout at work. Results showed that stress dimensions, such as the precariousness of the contractual status, the intention to change services, work overload, stress from the work-home interface, relationships at work, leading training activities, and dealing with patients predicted the three dimensions of burnout—physical fatigue, cognitive weariness, and emotional exhaustion. Therefore, these findings contribute to increase the knowledge of health professional's mental conditions, and can be used to design and implement interventions to mitigate the effects of stress and burnout on these professionals.

Keywords Occupational stress · Burnout · Health professionals

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1 Introduction

Occupational stress and burnout have become such a prevalent issue that the World Health Organization characterizes work-related stress as a global epidemic [1]. Stress can be defined as the relationship between the stress felt by the person and the psychophysical responses it elicits [2]. It is generally accepted that stress occurs when environmental demands overcome the person's capacity to adapt, leading to a negative impact on health and wellbeing.

In order to understand a person's adaptation to stress, Lazarus [3] proposed a model with two processes of cognitive appraisal. Primary cognitive appraisal encompasses the initial evaluation a person makes when confronted with a potential source of stress, in which the individual gives meaning to the situation, classifying it as threatening or challenging. Secondary cognitive appraisal relates to the way a person evaluates what can be done to deal with the situation, which involves considering the coping resources in order to manage the situation's demands. When demands are continuously perceived as exceeding the person's coping resources, especially in a long-term stressful situation, burnout can occur. Burnout can manifest through anxiety, headaches, insomnia, agitation, and sufferance, and physically through higher sensitivity to pain, higher susceptibility to infections, and stomach, cardiac, and vascular problems [4, 5].

Occupational stress is one particular context in which stress and burnout can occur. It results from people's inability to deal with sources of stress at work when they surpass their personal resources. The consequences to their physical and mental health, and to work satisfaction and engagement affect not only the individual but also the organization [6].

One of the most stressful working environments experienced by health professionals is the hospital setting. This experience is mostly due to the high incidence of work overload; shift irregularity and night shifts; high number of patients; ambiguity and role conflict; high responsibility for patients' lives; lack of autonomy; and the need to deal with constant suffering, pain, and death [7, 8]. Ribeiro and colleagues [8], for example, found that nurses working in a hospital presented significantly high levels of work stress related with leading training activities, working with patients, work overload, and with concerns about career progression and salary. Furthermore, focussing on long-term stress conditions experienced by nurses, Gomes et al. [9] concluded that several factors contribute to a higher probability of developing burnout syndrome: high levels of responsibility, low decision-making capacity, lack of career progression opportunities, bureaucratic or deficient management, and lack of support. Thus, health professionals are at a greater risk of experiencing burnout, which can lead to serious consequences in terms of the health care they provide. Additionally, the negative impact of occupational stress and burnout on professionals' health and well-being lead to less job satisfaction, physical and psychological complaints, and higher rates of turnover and absenteeism [10].

Given this panorama, this study aimed to analyse the relationships between stress and burnout. Specifically, we attempted to determine which stress dimensions predict the burnout dimensions of physical fatigue, cognitive weariness, and emotional exhaustion in health professionals working in a hospital in the North of Portugal.

2 Methods

2.1 Design

This was a quantitative and cross sectional study, with an exploratory, descriptive, and correlational nature.

2.2 Participants

The study included a convenience sample of 221 health professionals (20.4% doctors and 79.6% nurses) working in several medical specialties, from a hospital in the northern region of Portugal. Participants' ages varied between 22 and 65 years old (M = 37.73; SD = 9.15) and the majority were female (76.6%). Most were married (59.7%) and with children (62.4%). The vast majority worked full-time exclusively at the hospital (74.2%). Finally, most participants engaged in some form of physical activity (51.2%), as well as having a hobby (47.5%). All participants were informed about the nature and objectives of the study and signed informed consent forms to ensure their voluntary participation. Every procedure followed all ethical principles outlined in the Declaration of Helsinki, and the study was submitted to and approved by the Ethics Committee of the hospital where the data collection took place.

2.3 Measures

The evaluation protocol included a Sociodemographic and Professional Questionnaire, and the following instruments of psychological assessment, both validated for the Portuguese language:

Stress Questionnaire for Health Professionals (SQHP [11]). Evaluates six stress dimensions: (i) working with patients, (ii) relationships at work, (iii) work overload, (iv) career progression and salary, (v) leading training activities, and (vi) work-home interface. The items were measured on a 5-point Likert scale (0 = *No stress at all*; 4 = *Very high stress*). Higher scores indicate higher perception of stress in each domain, thus pointing to potential sources of stress at work.

Shirom-Melamed Burnout Measure (SMBM [12]; Portuguese version [13]), which evaluates burnout at work in three dimensions: (i) physical fatigue, (ii) emotional exhaustion, and (iii) cognitive weariness. The items were measured on a 7-point Likert scale (1 = *Never*; 7 = *Always*). Higher scores indicate higher levels of fatigue, exhaustion, and weariness, thus pointing to higher levels of burnout.

3 Results

Parametric tests were performed after all corollaries were met. Confidence intervals were defined at 95%, with an alpha level of .05 as the threshold for significance. Results were obtained through univariate and multivariate analyses of variance, using IBM SPSS (25). We used hierarchical regression analysis in order to analyse the independent effect of stress dimensions on burnout. To do so, we considered three blocks of variables entered as follows: step 1 included the socio-demographic variables, step 2 the professional variables, and step 3 the stress dimensions (SQHP).

3.1 Predicting Physical Fatigue

To analyse the predictive effect of stress dimensions on physical fatigue, a hierarchical regression model was conducted (Table 1).

The regression model in Table 1 significantly predicts physical fatigue ($F = 8.95$, $p < .001$), explaining 40.7% of the total variance. Specifically, it shows that participants with precarious work status ($\beta = -.145$) and those who intend to change service ($\beta = .149$) present more physical fatigue at work. Additionally, health professionals that report high levels of stress related to work overload ($\beta = .366$) and to the work-home interface ($\beta = .292$) exhibit greater physical fatigue.

3.2 Predicting Cognitive Weariness

The regression model shown in Table 2, testing for the independent effects of stress dimensions on cognitive weariness, was significant ($F = 10.452$, $p < .001$), and explained 32.7% of the total variance. Participants with children reported greater cognitive weariness ($\beta = .125$), which was also predicted by the experience of high levels of stress related to the work-home interface ($\beta = .201$), and to work overload ($\beta = .245$).

Table 1 Regression model for predicting physical fatigue (N = 221)

Predictors for physical fatigue (SMBM)	R^2 ($AdjR^2$)	$F(df)$	β	T	p
Step 1	.028 (.024)	6.183 (1,213)			
Having children[a]			.091	1.546	.124
Step 2	.152 (.131)	7.479 (5,209)			
Contractual status[b]			−.145	−2.393	.018
Place of work[c]			−.031	−.559	.577
Changing hospitals[d]			.017	.245	.807
Changing services[e]			.149	2.153	.033
Step 3	.437 (.407)	14.344 (11,203)			
SQHP-dealing with patients			−.052	−.721	.471
SQHP-relationships at work			.039	.542	.589
SQHP-career progression & salary			−.037	−.474	.636
SQHP-work overload			.366	4.711	<.001
SQHP-home-work interface			.292	3.830	<.001
SQHP-leading training activities			.028	.425	.671

[a]Dichotomous variable: 0 = no, 1 = yes
[b]Dichotomous variable: 0 = precarious, 1 = non-precarious
[c]Dichotomous variable: 0 = hospital only, 1 = hospital and other
[d]Dichotomous variable: 0 = no, 1 = yes
[e]Dichotomous variable: 0 = no, 1 = yes

3.3 *Predicting Emotional Exhaustion*

Table 3 shows the hierarchical regression model testing the predictive effect of stress dimensions on emotional exhaustion. Stress predicted emotional exhaustion (F = 8.723, p < .001), explaining 28.4% of the total variance. Having children was related to increased emotional exhaustion (β = .166). Likewise, higher levels of stress concerning relationships at work (β = .212), work overload (β = .210), work-home interface (β = .178), and leading training activities (β = .166) predicted more emotional exhaustion in health professionals. Yet, increased levels of stress related to dealing with patients, predicted less negative feelings of emotional exhaustion (β = −.235).

Table 2 Regression model for predicting cognitive weariness (N = 221)

Predictors for cognitive weariness (SMBM)	$R^2(AdjR^2)$	$F(df)$	β	t	p
Step 1	.023 (.019)	5.064 (1,213)			
Having children[a]			.125	1.993	.048
Step 2	.100 (.079)	4.656 (5,209)			
Contractual status[b]			−.023	−.352	.726
Place of work[c]			−.014	−.232	.817
Changing hospitals[d]			.036	.488	.626
Changing services[e]			.132	1.791	.075
Step 3	.362 (.327)	10.452 (11,203)			
SQHP-dealing with patients			.066	.860	.391
SQHP-relationships at work			.031	.397	.692
SQHP-career progression & salary			.049	.591	.555
SQHP-work overload			.245	2.961	.003
SQHP-home-work interface			.201	2.466	.014
SQHP-leading training activities			.087	1.256	.210

[a]Dichotomous variable: 0 = no, 1 = yes
[b]Dichotomous variable: 0 = precarious, 1 = non-precarious
[c]Dichotomous variable: 0 = hospital only, 1 = hospital and other
[d]Dichotomous variable: 0 = no, 1 = yes
[e]Dichotomous variable: 0 = no, 1 = yes

4 Discussion

Stress and burnout are increasingly common nowadays, especially in work environments. Hospital health professionals, given the inherent characteristics of their work, are at an especially high risk of suffering from the debilitating effects of stress and burnout, both of which can have a negative impact on their health. Therefore, this study aimed to explore sources of stress related to work that could predict burnout in hospital health professionals, in order to increase the knowledge of these individuals' mental conditions. These findings can be used to design and implement interventions to mitigate the effects of stress and burnout on these professionals.

Results showed that the dimension of burnout, namely physical fatigue, was significantly predicted by work stress, with higher levels of occupational stress being associated with increased physical fatigue. The main predictors of physical fatigue were the precariousness of the contractual status, the intention to change services, work overload, and stress from the work-home interface.

The dimension of burnout, namely cognitive weariness, was predicted by work stress, with increased levels of stress being related to greater cognitive fatigue. The main sources of occupational stress that become relevant predictors of cognitive

Table 3 Regression model for predicting emotional exhaustion (N = 221)

Predictors for emotional exhaustion (SMBM)	$R^2(AdjR^2)$	$F(df)$	β	t	p
Step 1	.039 (.034)	8.595 (1,213)			
Having children[a]			.166	2.564	.11
Step 2	.130 (.109)	6.258 (5,209)			
Contractual status[b]			−.017	−.262	.793
Place of work[c]			.036	.582	.561
Changing hospitals[d]			.094	1.241	.216
Changing services[e]			.119	1.571	.118
Step 3	.321 (.284)	8.723 (11,203)			
SQHP-dealing with patients			−.235	−2.962	.003
SQHP-relationships at work			.212	2.663	.008
SQHP-career progression & salary			−.014	−.160	.873
SQHP-work overload			.210	2.466	.014
SQHP-home-work interface			.178	2.116	.036
SQHP-leading training activities			.166	2.330	.021

[a]Dichotomous variable: 0 = no, 1 ± yes
[b]Dichotomous variable: 0 = precarious, 1 = non-precarious
[c]Dichotomous variable: 0 = hospital only, 1 = hospital and other
[d]Dichotomous variable: 0 = no, 1 = yes
[e]Dichotomous variable: 0 = no, 1 = yes

weariness were work overload and stress from the work-home interface. Those with higher cognitive weariness were more likely to experience higher levels of stress.

Finally, regarding emotional exhaustion, findings revealed that work stress exerted an independent effect on this dimension of burnout. The sources of occupational stress that become predictors of emotional exhaustion in hospital health professionals were relationships at work, work overload, work-home interface, leading training activities, and dealing with patients. Although, while for the majority of those predictors, increased stress experience was related to improved emotional exhaustion, high levels of stress in dealing with patients predicted reduced negative feelings of exhaustion in health professionals.

The majority of these results are in line with previous studies [5, 14], who point to overwork, work status, work with patients, and relationships at work as the variables that contribute the most to stress. However, it is interesting to note that, in this study, working with patients presented itself as a protective factor against emotional exhaustion and, consequently, stress, which contradicts most studies (e.g., [5, 9]). It could be that the emotional and social rewards of working with patients surpass the possible negative effects of stress. In fact, hospital health professionals tend to be highly engaged in their work, drawing personal satisfaction from contact with patients and from being able to care for and provide them with comfort. Still, it is an issue that merits further research in order to fully understand its process and consequences.

The burnout dimensions of physical fatigue, cognitive weariness, and emotional exhaustion were all significantly predicted by occupational stress factors. Taken together, these results underscore the importance of designing and implementing interventions that target these variables to promote better adaptation of health professionals to their stressful work environments. Consequently, such interventions, along with hospital management and ministry offices, should aim to reduce physical fatigue by ensuring health professionals have a secure work status and are not overloaded in the amount of work required. The latter would also contribute to lower individuals' emotional exhaustion. More support should also be allocated to health professionals who intend to change service, both logistically and psychologically. Lastly, given the influence of the work-home interface, with respect to physical fatigue, cognitive weariness, and emotional exhaustion, hospital managers should strive to provide adequate support to their professionals, by offering more flexibility and psychology services that teach strategies to make the demands at home and work more compatible.

To target the cognitive weariness dimension, public decision makers must ensure that health professionals are not overloaded. Although recognizing the financial implications for hospitals in hiring more staff, it is imperative that hospital staff are given adequate workloads, since overload is implicated in cognitive weariness and, consequently, stress levels, both of which have a negative impact on hospital staff's psychological and physical health. Moreover, overloaded professionals are more prone to errors, thus endangering their patients. Results also showed that nurses without children showed less cognitive weariness. Therefore, health professionals who do have children should have institutional support to facilitate juggling their professional and personal lives, namely by arranging to have day-cares within their facilities and staff dedicated to teach techniques to deal with these personal/work life demands.

Finally, professionals with no children and who work more with patients report less emotional exhaustion. Again, the same techniques mentioned above should be used for professionals with children with the aim of reducing their emotional exhaustion. Moreover, given the apparent protective quality of working more with patients, it could be argued that hospitals should ensure a balanced distribution of patients per professional, guaranteeing that all health professionals have the opportunity of working with patients and thus benefit from their protective quality. On the other hand, professionals with more stress in their relationships at work and those who design and implement public presentations in leading training activities present with higher emotional exhaustion. In order to target these variables, teams of psychologists should be available to deliver interventions that focus on work relationships and how to ensure healthy work environments. Concomitantly, the same teams could implement training sessions to teach health professionals how to design and implement public presentations, how to deal with the stress they cause, and to teach leadership skills invaluable not only to these presentations, but also to their work lives and relations, along with their private and personal lives. Future research should include other health professionals in their samples, in order to increase professional representativeness and thus increase the perspective on stress and burnout in health professionals.

In sum, health professionals are at high risk of suffering from physical fatigue, cognitive weariness, and emotional exhaustion stemming from the presence of high levels of occupational stress. Interventions should be implemented in hospitals with the aim of targeting occupational stress variables that have an impact on physical fatigue, cognitive weariness, and emotional exhaustion.

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Effects of Sunlight on Psychological Well-Being, Job Satisfaction and Confinement Perception of Workplace: The Case of Shopkeepers and Marketers

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Abstract This study has as main objective to observe the difference in job satisfaction, psychological well-being and perceived confinement of commercial workers due to solar exposure in the work space. For this purpose, a quasi-experimental design of non-equivalent groups with a unifactorial design of three conditions was carried out: null exposure (internal shopping stores); indirect exposure (street stores) and direct exposure (fairs and street markets). Participants, out of a total of 184 answered a self-reported questionnaire applied at the workplace. The results showed that the participants in the direct exposure work places present superior mean values in the variables compared to the other conditions' participants. Perceived confinement has a predictive effect on job satisfaction and on psychological well-being, which meets what was expected.

Keywords Artificial light · Job satisfaction · Perceived confinement · Psychological well-being · Sunlight

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1 Introduction

The literature has pointed to a number of non-visual effects of sunlight on people by providing the spectral energy distribution necessary for a broad set of biological functions (e.g., [1]). In addition to the tan tones so sought after by most people, the positive effect on rickets, the synchronization of various physiological rhythms and the control of infantile jaundice, the production of melatonin (e.g., [2–4]) or in mood and anxiety (e.g., [5, 6]) are some of the effects to emphasize. As a result, people who work outdoors or with easy and frequent access to the open air during their working time have their needs for the stimulation of sunlight satisfied and the quality of the interior lighting to which they may be exposed has no significant negative effects. For other workers working in indoor environments, without sunlight (e.g., mines, submarines, cellars), the psychological well-being is lower (e.g., [1, 5, 6]). Of course, the full-spectrum fluorescent illumination that can be found in these spaces also provides substantially all of the spectral energy distribution. However, the light levels are much lower than daylight levels and depends on the lighting options that those responsible have assumed (e.g., [4]). For example, the spectra of incandescent, white and high-pressure sodium vapor light sources appear to be insufficient to cover the entire spectrum of photobiological action of importance to humans [7].

In terms of sun exposure, we can divide the environment into three types: (a) direct sun exposure, i.e. without any interference from barriers (e.g., outdoors); (b) indirect solar exposure, i.e. where exposure to sunlight is through glass or other elements and (c) null sun exposure, i.e., total absent of sunlight. The latter type is characteristic of the working environment of the employees of fully-interior stores and supermarkets in shopping centers. Although the color of light affects different degrees of confinement perception, studies show that spaces with artificial lighting are perceived as more confined than spaces with solar lighting [8]. These spaces, besides having zero (or almost null) sun exposure, the access to the exterior is infrequent, contributing to spaces perceived as being confined. These workers live in a different visual environment of open spaces. The vision is limited to a few meters without the possibility of framing objects close to the position of a horizon [9]. Some studies point to the effect of a decrease in job satisfaction and psychological well-being and an increase in stress in workers operating in spaces with limited access to outdoor [10, 11], in particular in these professionals [12, 13]. Job satisfaction (JS), understood as an attitude towards work, and psychological well-being (PWB) are two variables that are highly associated with motivation, engagement, performance, productivity, quality of life at work, turnover intention, among other outcomes (e.g., [14–16], see also [17]). However, studies that analyze these variables in relation to the degree of exposure in store sellers are still scarce, especially when it is considered workers with high direct sun exposure (for example, outdoor sellers) and in particular when the work environment does not consider environmental physical variables (e.g., [18]). Thus, it was the objective of this study to compare JS, PWB and perceived confinement (PC) in commercial workers as a function of the degree of sun exposure. It is our expectation that workers with greater direct sun exposure present higher values of JS, PWB and lower PC values. We also expect to see an effect of PC in JS and PWB.

2 Method

Considering that direct and indirect sun exposure has different effects (for example, only direct sunlight stimulates vitamin D), we also distinguish between these. Thus, a quasi-experimental design study of nonequivalent groups was developed based on a unifactorial design 3 (Solar exposure: null vs. indirect vs. direct). The independent variable was operationalized according to Table 1.

2.1 Sample and Procedure

A convenience sample of 184 participants (116 women and 68 men) is aged between 17 and 73 years (M = 34.47; SD = 11.43). About 57.1% of the participants have secondary education or equivalent courses, 16.3% have basic education and 26.6% have a university degree. Most respondents are employees (93.5%) and 6.5% are self-employed entrepreneurs (all from the direct condition). Concerning our independent variable, in the null condition: 70 participants (38%); in the indirect condition: 61 participants (33.2%); and 53 participants (28.8%) in the direct condition. Regarding the biographic variables, the participants in the direct condition presented a mean age (M = 42.26; SD = 13.39) significantly higher than the participants from the other two conditions.

Participants were asked to answer a self-report questionnaire with an average completion time of 10 min. Data collection was performed individually and with the investigator's presence in the workplace. Only the questionnaires completed correctly were included in the analysis.

2.2 Measures

A self-report questionnaire composed of sociodemographic items and the following instruments:

Table 1 Operationalization of the independent variable

Sun exposure	Commercial space
Null	Shopping centers shops and supermarkets
Indirect	Street shops
Direct	Fairs and street markets

Job satisfaction: Developed by Warr et al. [19], and adapted to the Portuguese population by Santos et al. (submitted). This scale is unidimensional and consists of 16 items relating to various aspects of the work that affect the job satisfaction and the answers are given through a 7-point Likert scale (1—totally unsatisfied to 7—totally satisfied). This scale contemplates items such as "Salary" (item 7), "Promotion opportunities" (item 10), and "Work schedule" (item 13). The scale presented a good internal consistency value ($\alpha = 0.93$).

Psychological Well-Being (GHQ12): Developed by Goldberg and Williams [20], and adapted to the Portuguese population by Gonçalves et al. (in preparation). It is a one-dimensional measure that assesses psychological well-being through 12 items pertaining to two aspects, the inability to perform normal functions and the emergence of new and distressing experiences. The answers are given through a 7-point Likert scale (1—Totally disagree to 7—Totally agree). Items 2, 5, 6, 9, 10 and 11 were reversed (e.g., item 4: "I felt able to make decisions"). The scale, in this study, presented a good internal consistency reliability ($\alpha = 0.77$).

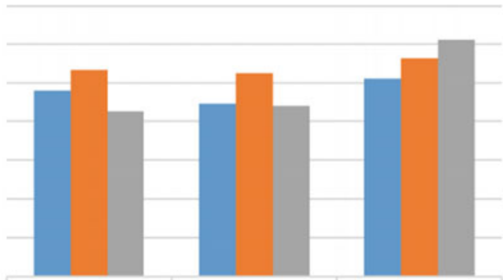
Perceived confinement: 4 questions were elaborated and tested based on the confinement perception construct (e.g., [12, 21]). The answers are given through a 7-point Likert scale (1—Totally disagree to 7—Totally agree). Two items were reversed (e.g., item 1: "I feel physically confined" thus, the higher the mean more comfortable (less confined) the participant felt). An internal consistency value of 0.87 was observed in the present study.

3 Results

Descriptive and inferential analysis

As can be observed in Fig. 1, the direct sun exposure condition participants present a higher mean in the three variables compare to all participants of the other conditions. Based on the design 3 (Solar exposure: null vs. indirect vs. direct), an ANOVA between groups showed an effect of the independent variable for all variables (PWB: $p < 0.006$; JS: $p < 0.012$ and PC: $p < 0.000$). The Tukey HSD test showed that the JS of the direct condition participants is significantly superior to the indirect conditions' participants ($p < 0.008$). Regarding the PWB, the participants of direct exposure presented values significantly superior to the remaining participants ($p < 0.006$ and $p < 0.04$). Linear regression analyzes were performed to observe the effect of PC on JS and PWB. The results show that the PC explains about 14.1% of the JS ($\beta = 0.375$, $p = 0.000$) and about 10% of the PWB ($\beta = 0.351$, $p = 0.000$).

Fig. 1 Variables means for each condition



	Null (Shopping)	Indirect (Street Shops)	Direct (Street Markets)
JS	4,79	4,47	5,11
PWB	5,34	5,24	5,66
PC	4,27	4,42	6,12

Note: JS (job satisfaction); PWB (psychological well-being); PC (perceived confinement)

4 Discussion and Conclusion

In this, we compare shopkeepers and marketers JS, PWB and PC in function of the sun exposure during the work activity. The literature presents an enormous theoretical and empirical foundation of the contributions of sun exposure in physical and mental health (e.g., [3, 6]). Although the management and design of the workspace is not yet a priority for most organizations, the benefits of sun exposure for workers and, consequently, for organizations are many. Studies have shown benefits in attitudes towards work and well-being, among other outcomes (e.g., [16]) which in turn contribute positively to performance and productivity [17]. Many shopping centers both in Portugal and in other countries are completely closed to the sun exposure, so that their workers spend a lot of time without direct sunlight. Considering that sunlight contributes to psychological well-being among other outcomes, then its absence negatively affects individuals [3, 6]. With this purpose we have developed a quasi-experimental study of non-equivalent groups where we integrate, in comparative terms, indirect and direct solar exposition spaces, in particular fairs and street markets, which have been little studied. According to our expectations, workers in direct sunlight expose better JS, PWB and less PC (remember that for the analysis the variable was inverted).

The regression analysis showed that the PC is a predictor of both JS and PWB.

The methodology used, quasi-experimental, has some advantages, as it is the case of being in a real (non-laboratory) environment, but it presents several limitations with regard to the control of other variables that can affect the results. In this case, there are several limitations both to the characteristics of the environment (light, area, design, furniture, etc.) and to the participants. However, in relation to the light environment, it should be noted that this effect must be analyzed in interaction with two aspects that were not evaluated and that affect the variables of physical and psychological health, the sources, light characteristics (photometric properties, etc.) and location of light sources and light distribution (e.g., [22]) and the size of the stores. Both variables affect the perception of confinement, a variable positively associated with anxiety, stress, mood, etc. In this regard the type of illumination (white-yellow vs. bluish-white light) affects perceived photometric intensity (Helmholtz-Kohlrausch effect) (e.g., [23]) and the shadows produced in space by altering the perception of available space (e.g., [24]). The type of lighting also affects involvement in mental effort [25] and consequently, the state of fatigue and well-being.

With regard to the participants, in addition to the number of participants limiting more complex analyzes, the visual characteristics associated with lighting may imply more mental effort to some workers compared to others. Some of the biographical characteristics of the participants are not equivalent between the conditions, is the case of the age that is positively associated with job satisfaction (e.g., [26]). In our study, participants in the condition of direct sun exposure had a mean age significantly higher than the other participants. Therefore, it is a complex process with a wide set of variables in interaction that implies the need for more studies.

It is true that there has long been a growing and significant concern of architects and designers in integrating into their projects the psychological variables contributing to the design of interior spaces adjusted to ergonomic criteria and health that maximizes the comfort and physical and mental health of the occupants (students, employees, residents) [27]. However, the mental health of store employees still seems to be a low priority for aesthetic and consumer promotion needs. It is important for companies to understand that the natural environment and in particular sunlight can be an antidote to work stressor variables and fatigue restorers (e.g., [5, 28]). The measurements do not have to be physical changes of the workplace, they can be replaced by a definition of schedules and pauses that allow greater contact with direct sunlight.

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Dangerous and Precarious Work and the High Cost of Emotional Demands Controlled by Alcohol: A Systematic Review

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Abstract The literature review supported by six databases on the harmful use of alcohol in dangerous and precarious working conditions revealed links between alcohol and psychosocial risks that emerge from several occupational contexts. Our goal is to provide evidence whether the harmful use of alcohol has expression under such conditions and which factors favor it. In these unsafe workplaces, the emotional demand is high and the workforce is usually defined by men, among whom alcohol abuse grows both inside and outside of workplace, affecting the longevity of workers. In 2016, the global alcoholic legacy exceeded 132 million disability-adjusted life years, about a half was caused by mental disorder and 40% by traumatic injury. It also exceeded 3 million deaths, 75% occurred among men. Alcoholization may be an underlying blocking symptom during the construction of the individual's identity, where the work has a mediator function and may not necessarily be practiced by an alcoholic. Moreover, alcoholization can be a defensive strategy created and maintained by the collective of workers to emotional demand control and make work feasible. Our review suggests that controlling the emerging emotional demand of these workplaces may cost the rise of alcohol-related illnesses and injuries inside and outside the workplace. In concrete, it is complex to characterize the causal nexus with work under the effect of alcohol and the tendency is under-reporting of work-related disorders. Intervention in "pathogenic workplace" can produce long-lasting effects and on the opposite path to the alcoholization of workers, who are still "healthy".

Keywords Alcohol · Danger · Work

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1 Introduction

1.1 Alcohol in Numbers

In 1948, the World Health Organization (WHO) recognized alcoholism as a disease and warned society that alcohol was one of the most serious socioeconomic problems for global health. In 2012, the harmful use of alcohol (HUA) caused 6% of global deaths, which totaled 3.3 million deaths [1]. By 2016, more than 3 million people continue to die as a result of HUA. This represents 1 in 20 deaths. More than 3/4 of these deaths were caused among men [1]. According to ILO, 40% of work-related accidents directly or indirectly involve alcohol consumption in the workplace [2].

Given this global accounting, we justify the relevance of this review, focused on identifying the contributive and aggravate psychosocial factors of the "alcohol risk" [3] that emerge from dangerous and precarious workplaces. E.g., Marble and Granite Mining Industry—MGMI [4, 5], whose workers are the protagonists of our future research.

1.2 Alcoholism and Alcoholization

Alcoholism or alcohol dependence (AD) is understood as "a chronic and continuous mode of use of alcoholic beverages, characterized by periodic uncontrolled of the consumption or by a pattern of alcohol consumption with frequent episodes of intoxication and concern with alcohol and its use, despite the adverse consequences of this behavior for life and health" [3].

A single risk that affects population health in "230 three-digit disease and injury codes in the International Statistical Classification of Diseases and Related Health Problems—ICD-10: infectious diseases, non-transmissible diseases (cardiovascular, hepatic, mental, neurological, etc.) and traumatic injuries" [1]. Recognizing harmful use of alcohol (HUA) as a development issue in itself is the new vision of the United Nations and expressed in its Sustainable Development Goals (SDG). The WHO warns that, "reducing HUA is the cornerstone for sustainable development" [1].

To define alcoholization (ALC), in our view, it is fundamental to rediscover an ancient theory and its contributions to the longevity of humanity [6]. "Ledermann's theory of the epidemiological distribution of alcohol consumption" started with data from the French population, but affected the world population later. Ledermann observed that in certain regions of France, with high rates of alcohol consumption, the death rate from liver cirrhosis and other alcohol-related diseases was higher than the rates of "heavy drinkers" (>50 L per year), a phenomenon called by the French professionals of "alcoholization of society" [7]. According to theory, two populations with the same pattern of per capita alcohol consumption have the same prevalence of "heavy drinkers". There was a relationship between per capita consumption among drinkers in the population as a whole and the rate of "heavy drinkers" in the population [7].

The theory spread rapidly in different countries as a guide to public anti-alcohol policies, focusing on reducing the average alcohol consumption of the "healthy" population, to reduce the pathologies. The new paradigm was to reduce average drinkers with the potential to become future "heavy drinkers" and no longer focus on reducing "heavy drinkers" with rooted and already dependent consumption habits [6].

The great originality of the Ledermann's theory was exactly the distinction between AD and ALC, since now the graduation of the pattern of consumption and "absorption of alcohol has a fundamental statistical value" [7]. Absorption would be what occurs when an individual is alcoholized, that is, when alcohol is introduced and can rapidly attain intoxication. It differs greatly from AD, whose symptoms only become visible after a long period and lead to chronic intoxication without drunkenness.

The term "alcoholization" was introduced in the "Lexicon of terms on alcohol and drugs", published in 1994 by WHO [8].

1.3 'Psychosocial Risks'

Preliminarily, it is important to distinguish "psychosocial risks" from their effects [manifestations] on physical, mental and social health, because it "is not their psychosocial effects that make them a health risk at work, but rather their origin" [9].

"Psychosocial risks" are defined as the "risks to mental, physical and social health caused by employment conditions and organizational and relational factors that can interact with mental functioning" [9].

2 Aim

Our purpose in this review is to provide a comprehensive overview on the possible relationships between harmful use of alcohol and contributory, provoking or aggravating psychosocial risks emerging from dangerous and unsafe work environments. Moreover, to identify the tools used in the studies to evaluate the motivations of HUA by workers with practical applicability in our future research.

In what kind of work does HUA have expression? What are the working conditions that favor HUA? We suspect that, in Brazilian stones workers in MGMI, alcohol-related accidents and illnesses are targets of underreporting its causal nexus with work, and this is a hypothesis for which we will seek answers.

3 Methods

Systematic review in English and Portuguese, no date criteria and in 4 databases (Academic Search Complete, Scopus, Scielo and Web of Science) to investigate original studies carried out in different economic sectors, but with similar characteristics to the work or to the workers of the MGMI and with focus on the work-related alcohol consumption issue. More specifically, sectors inhabited mainly by men, with low schooling, with manual labor and activities in dangerous or precarious environments.

The initial intention was to have as inclusion criteria the selection of studies done only with MGMI workers, but we did not find any study developed in this industry and focused on the alcohol problem. For this reason, we have broadened our criterion.

Articles were identified using 20 keyword combinations. Other sources consulted: http://www.fundacentro.gov.br/rbso and http://laboreal.up.pt/. Other criteria applied: only human research with the Ethics Committee and the Consent Term, reproducible studies, but regardless of the methodological approach.

4 Results

Our eligibility process (see Fig. 1) resulted in the selection of 15 articles of studies conducted in the following countries: 5 from Brazil, 4 from the United States of America, 2 from Finland, 2 from the United Kingdom, 1 from Sweden and 1 from Uganda. The Table 1 shows the results of the eligible articles.

Our selection was composed by studies conducted under different perspectives, e.g., sociology, medical sciences, work psychopathology and psychodynamics included studies that privileged workers' perception. As for the methods, 5 studies were conducted with qualitative approaches and the other 10, quantitative analytical approaches.

Three tools were identified to assess the work-related alcohol problem. The AUDIT - Alcohol Use Disorders Identification Test was developed in the year 1992 by the WHO aiming at the early detection of "problematic drinkers". This study introduced the original concept of Zones of Risk, focusing on the prevention of HUA and, therefore, of diseases and accidents. The second and simpler tool, CAGE, aims to detect the "problematic drinker", suspected of AD. Its acronym corresponds exactly to the initial letter of each of its 4 items: "Cut down,"

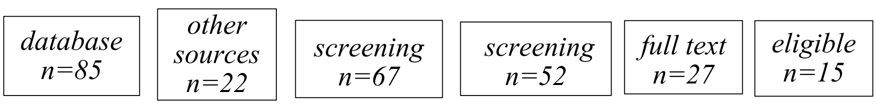

Fig. 1 Diagram of the eligibility process

Table 1 The results of the eligible articles

Author, year	Country	Design	Sample	Results
Araújo, 2018	Brazil	CSS	n = 7 ♂ n = 54 ♀ w: waste pickers	AUDIT: 23 cases (Z: 1 and 2) and 4 cases (Z: 3 and 4)
Cunha, 2016	Brazil	CSS	n = 1362 ♂ n = 199 ♀ w: urban drivers	CAGE: prevalence of HUA 13.5%. Link: SM versus WRA whit injuries
Haas, 2016	USA	ED	n = 47 ♂ w: motorcyclists, mineworkers	Issue: risky behavior (DS?) and peer pressure (ICW?). 'I'm a fairly experienced drinker (…) limit 3 beers within a 5 h'
Leino, 2012	Finland	CSS	n = 1557 ♂ n = 177 ♀ w: police officers	Link: SM versus WR injury ≥ 1 injury: >4 risk HUA, >4 risk MS, >2 risk fear of future violence than suffered no injury
Dolan, 2011	UK	ETS	n = 22 ♂ w: blue and white collars industries	Issue: SES versus risky health practices. Low SES > poor practices (e.g., HUA). Moreover, ICW and DS with glazier and butcher. Greater SES: 'They have more to live' (>advantages and desire for self-preservation). Low SES: 'Has no life; has no desire'!
Tumwesigye, 2009	Uganda	CSS	n = 722 ♂ n = 757 ♀ w: 50% unskilled and farmworker	Relationship: SI versus HUA greater SI >2 times risk than low SI to drink alcohol ≥ 3 times/week (ICW?)
Makela, 2008	Finland	LS	n = 180 ♂♀ w: SD (blue and white collars)	Link: alcohol-related death and hospitalization versus workforce. MW >2 times risk than non-MW
Mabuchi, 2007	Brazil	ED	n = 91 ♂ n = 9 ♀ w: waste collectors	QACP: prevalence of HUA 94% and AD 15%. Motivations HUA: 46% ICW; 12% humiliation; 9% excessive work hour load and smell of the garbage. Note: 61% merchants offering drinks

(continued)

Table 1 (continued)

Author, year	Country	Design	Sample	Results
Karam, 2003	Brazil	ETS	Proposal: the work has mediator function and word has lever function in the building of the individual's social identity	Certain working conditions lead to "workers' aphasia" that favors ALC = a "block signal" in this building. Transform "pathogenic work" in a direction opposite to that of ALC, otherwise the "sign" becomes the "causes of the block" (to later AD)
McLean, 2003	USA	CSS	n = 3476 ♂♀ w: SD	Link: hospitalizations and deaths by alcohol-related injuries versus work (cases: 2710 non-WRA and 766 WRA). CAGE +: 36% WRA and 35% non-WRA
Lipscomb, 2000	USA	CSS	n = 3955 ♂ w: SD dead construction	Link: positive alcoholemia (≥ 0.50 g/l) versus deaths from accidents inside and outside the workplace. Accidents outside had 57% positive and inside only 5%
Lima, 1999	Brazil	RC	n = 335 ♂ w: oil refinery	CAGE +: 98 cases and 23 cases systemic arterial hypertension
Hemmingsson, 1998	Sweden	LE	n = 37,362 ♂ w: SD blue and white collars	Prognosis of HUA in young workers (303 cases of psychiatric AD): blue collar has >2 times risk than white collar of mental disease to later. Monotonous jobs > risks
Zwerling, 1996	USA	LE	n = 7089 ♂♀ w: SD	Injuries and CAGE +: blue collar has >2 times risk and >3 times risk than white collar, respectively
Aiken, 1982	UK	CCS	n = 213 ♂ w: offshore oil rig	30% HUA above safe limits in the week prior to the offshore period

Legend alcohol dependence (AD); alcoholization (ALC); cross-sectional study (CSS); defensive strategies (DS); empirical theoretical study (ETS); exploratory descriptive (ED); harmful use of alcohol (HUA); influence of the collective of workers (ICW); longitudinal study (LS); manual workers (MW); mental suffering (MS); secondary data (SD); social interaction (SI); socioeconomic status (SES); workers (w); work-related (WR); work-related accidents (WRA); Zones (Z). The use of quotation marks indicates the voices of the workers. The codes AUDIT, CAGE and QRCAP refer to the tools applied in the studies, already described in the results

"Annoyed by criticism," "Guilty about drinking," and "Eye-opener drinks." Its cutoff point has 2 positive answers. The QACP—Questionnaire on Alcohol Consumption with Profession was based on AUDIT with the its singularity of introducing the perception of the Brazilian waste collectors about the relationship between alcohol consumption and work, as well as the motivations for initiating HUA, and the consequences of the use at work. Some articles have investigated HUA for dichotomous and specific issues related to the object under analysis.

5 Discussion and Conclusion

Although no studies with MGMI workers were identified, our review is useful to answer at least 4 basic questions with practical applicability in our future research:

What is the work in which HUA has expression? In certain occupational contexts where hazardous work is performed under precarious and "anxiogenic" conditions, namely, when there is life risk exposure to himself or his colleagues and high quantitative demands at work (work pace and working hours), evidence from research [11–13, 17, 20, 21, 24] point to a growing and progressive expression of ALC and AD.

What working conditions favour HUA? In the collective work and with favourable culture to HUA [12, 13, 17, 20, 24]; in continuous work [11–14, 17, 20, 23, 24]; in sectors with a predominance of manual workforce [14–17, 20, 22, 23] and strenuous work [23]; conditions of greater accessibility to alcohol inside or near the workplace [15, 17] and, paradoxically, also were in alcohol is sanctioned [11–13, 21, 24]. In the study of the sociological perspective, in workplaces defined in masculinity, workers of lower socioeconomic level present less desire for self-preservation, "risk health practices", including HUA [14]. It should be noted that in a collective work environment, with a predominance of manual work and little prestige, with exposure to smell of the garbage, but defined mainly by women in a Brazilian context, a better health practices and lower prevalence of HUA were observed [10]. Perhaps a greater feminization in the MGMI's workplace, inhabited by male hegemony, the arrival of more female colleagues may turn men's reflections on their "risky health practices" [14] towards the development of work [25, 26].

What relationships exist between HUA and the concrete demands of work? Our review provided evidences of the association between HUA and high quantitative demands at work, already discussed. E.g., excessive workload was one of the main reasons reported by garbage collectors for entering alcohol abuse [17]; the strenuous job almost doubled the risk of "heavy consumption" in manual workers [23]. The complaint from butchers and glaziers was "too much pressure" at work, despite the high risk of accidents with cuts. We identify "indirect signs of fear" illustrated by the classic dangerous collective ideologies, as an "attempt at symbolic domination of fear" [27]. In these sectors a collective of British butchers has created "arenas" of competition with fast knives and in the glass industry, was prescribed by veteran glaziers the culture of refusing to use of the anti-cut forearm protector [14]. The low prestige from the image of the profession was observed in garbage collectors [17]. Mental suffering, fear of developing mental disease (insanity) and fear of death were associated with daily work in dangerous and precarious workplaces [11–14, 17]. In Ugandan manual worker greater social interaction was associated with higher HUA risk [15] and nearly half of the garbage collectors in the Brazilian study argued that "friends' influence" was the major reason for joining HUA [17]. In blue collar workers, monotonous jobs were associated with double the risk of future dependence with psychiatric symptoms and the risk increased further if combined with low social support in the workplace [22]. The lack of support in the period after work-related injuries suffered or witnessed by police officers increased their alcohol consumption by almost 5 times [13].

Is HUA an effect/consequence and, at the same time, a defensive strategy against the harmfulness of work? If we contextualize Karam's ideas [18], in turn, derived in part from the Ledermann theory, we must reinforce that AD and ALC are distinct phenomena. Karam proposed that, in building the "social identity" of worker, the work has a mediator function and the word has a lever function. In organizations dominated by oppression, "worker aphasia" blocks this construction. The ALC would be a "block signal" of this construction and, at the same time, is a defensive ideology created by the collective for mental protection of all, despite the mental suffering being individual [18]. Two studies reinforce the prognostic significance of Karam's ideas. In Sweden, a prospective study observed double the risk of developing future alcoholism with psychiatric symptoms in unskilled manual workers [22]. Another study also showed double the risk of alcohol-related hospitalizations and death in unskilled manual workers [16]. Anti-alcohol programs should be redirected to "healthy" workers and their families, and no longer restrict to dependent workers [1, 2]. Therefore, a policy aligned with Lederman's and Karam's idea in betting on reducing population consumption, consequently, "keeping healthy workers healthy" [1]. Moreover, only alcohol sanction in the middle of work may not show expected efficacy and may further encourage the untying of work with alcohol-related illness and injury. Two studies focus on the extent of alcohol damage, which can extrapolate the physical limits of work and increase underreporting of alcohol-related occupational disease and injury, both inside and outside the workplace [19, 20]. In workplaces where alcohol is sanctioned, both HUA and AD were observed outside the workplaces [11, 12, 20, 21, 24].

We recommend anti-alcohol policies that focus on building a healthy, reliable, and safe workplace. "Work can't be just produce. To work is to transform the world, but it is, above all, to transform, to produce itself" [27]. Breaking the pathogenic side of "being together" by alcoholization in exchange for "being together" by "political word" [19] that's what society must do and may do if it wishes to protect workers from the most tragic outcomes: alcohol-related deaths, illnesses and injuries.

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The Prevalence of Burnout in Portuguese Physiotherapists

Adérito Seixas, Teresa Marques, Isabel Moreira-Silva, Joana Azevedo and Sandra Rodrigues

Abstract Burnout is a relevant issue among health professionals. Physiotherapists work daily with patients and witness both successes and failures in the rehabilitation process, exposing them to high levels of physical and emotional strain. The aim of this study was to assess the prevalence of burnout in Portuguese physiotherapists and to explore possible associations between burnout and demographic and work-related variables. Significant but weak association was found between age and emotional exhaustion, and between clinical experience and emotional exhaustion and global burnout score. Weak association was also found between the number of treated patients daily and daily working hours and physical fatigue and global burnout. Workload was associated with significantly higher scores of physical fatigue, cognitive weariness and global burnout. The prevalence of burnout was not high but significant differences were found in the prevalence of physical fatigue between the group with low workload and high workload. In conclusion, the results suggest that the prevalence of burnout is not very high, however, workload seems to place these professionals at a higher risk of developing burnout.

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Keywords Physiotherapy · Workload · Burnout

1 Introduction

Nowadays, humans are often busy, pursuing more income, career development and personal satisfaction. Humans work for more than half of their life span and it builds the pillars of human existence. The relationships that people establish in the workplace, and the difficulties that often arise when those relationships assume negative contours, have been recognized as a significant aspect of human lives in the present time. The term "burnout" appeared in the 1970s in the United States, mainly among human services workers [1]. Healthcare professionals are among such workers and are at high-risk of manifesting negative consequences from chronic exposure to work-related stress [2] and a recent meta-analysis has demonstrated that, in healthcare providers, burnout has negative associations with perceived healthcare quality, patient satisfaction, quality indicators and perceptions of safety [3].

The term "burnout" was coined by Freudenberger [4]. The author used the term to characterize the exhaustion of individuals, caused by excessive social and physical job demands. Burnout may be defined as a negative psychological reaction to chronic work stress exposure. Usually, the burnout syndrome is associated with three major dimensions, emotional exhaustion, depersonalization and cynicism, and low perception of personal accomplishment [4, 5]. These domains may be thought upon as a continuum starting with emotional exhaustion, i.e. perception of emotional stress and physical depletion. Subjects with emotional exhaustion feel indifferent about their work, no longer becoming invested in normal situations of a workday. As emotional exhaustion becomes more important, depersonalization and cynicism arise, with negative attitudes and detachment feelings towards work [2].

Other authors consider that the core content of burnout is the depletion of the individuals' intrinsic energetic resources over time and is reflected primarily in emotional exhaustion, physical fatigue and cognitive weariness [6–9]. This line of thought considers exhaustion to have a central role in the process, and in fact exhaustion is a key dimension in all theoretical perspectives of burnout. Exhaustion is the most widely reported and analysed component of the syndrome and, although this approach is not consensual [10], emotional exhaustion has been reported as the most prominent burnout characteristic in studies enrolling health professionals in general [11] and physiotherapists in particular [12], highlighting the importance of the component.

Previous research has been published on the topic of burnout in physiotherapists, enrolling professionals from several locations in the planet, such as Australia [13], Cyprus [14], Japan [15], Poland [16], Portugal [17], Spain [18] and United States [12], however, data from Portuguese physiotherapists is based in a small study and more information about this specific reality may provide valuable information towards the understanding and management of burnout.

Therefore, the aim of this study is to assess the prevalence of burnout in Portuguese physiotherapists and to explore whether any particular demographic and work-related factors are associated with an increased risk of burnout.

2 Methodology

2.1 Participants

The sample in this cross-sectional study consisted of physiotherapists working in 12 private clinics in the northern region of Portugal. Participants were recruited using a convenience sampling method after the approval from the Ethical Committee of the local University. All participants gave their written consent to participate in this study. The following inclusion criteria were adopted: having a degree in physiotherapy and being with direct contact with patients for at least 1 year.

2.2 Instruments

A two-part self-administered questionnaire was used for data collection. The first part consisted of a custom-made questionnaire aiming to characterize the sample regarding gender, age, working experience, daily working hours and number of patients treated. The second part was the Shirom-Melamed Burnout Measure (SMBM), which was constructed, based on the Conservation of Resources theory, as an alternative burnout instrument that focus on the assessment of exhaustion, i.e. the depleting of energetic resources, regardless of the occupational context [19]. The authors conceptualized burnout as a multidimensional construct with three fundamental aspects: physical fatigue, emotional exhaustion and cognitive weariness. Physical fatigue refers to perceptions of tiredness and low levels of energy performing workday tasks, emotional exhaustion refers to the perception of being too weak to display empathy to clients or coworkers and cognitive weariness refers to the perception of slow thinking processes and reduced mental agility [6, 8, 9]. A Portuguese version of the instrument was used in this study [20]. The instrument includes 14 items, distributed by the three subscales and each item is assessed in a 7-point Likert scale (1 = never; 7 = always). The score is obtained by summing up the items of each subscale and then dividing the result by the number of corresponding items, therefore, higher values mean higher levels of physical fatigue, emotional exhaustion and cognitive weariness. It is also possible to calculate a total score, obtained from the sum of the values in each subscale and then divide by three. Since there are no normative values available, a value of five, or higher, is an indicator of problems in a specific domain [20].

2.3 Procedures

The target institutions were contacted and after approval, 75 copies of the instruments were distributed. The participants had the opportunity to ask all the questions they considered relevant. The filled questionnaires were then collected by the same researcher. Of the 75 questionnaires, 71 (94.7%) were returned.

2.4 Data Analysis

Data was analyzed using the Statistical Package for the Social Sciences (SPSS) version 25.0 for Windows (SPSS Statistics, IBM, Chicago, IL, USA). Descriptive statistics were used to characterize the studied sample and interest variables. The Kolmogorov-Smirnoff test was used to assess the distribution of the studied variables, and since the variables did not follow a normal distribution pattern, non-parametric tests were selected. Spearman correlation coefficient was used to analyze the association between burnout scores and age, clinical experience, number of patients treated daily and number of daily working hours. A hierarchical cluster analysis was conducted to create groups based on the reported workload. Workload was objectively assessed using the daily working hours and daily number of patients treated. A two-cluster solution was achieved after an agglomerative approach, applying the between-groups linkage clustering method using squared Euclidean distance as measure. The independent samples Mann-Whitney U test was used to test if the cluster groups were different regarding the number of patients treated daily and the number of daily working hours and to compare the burnout scores between the two groups formed in the cluster analysis. The prevalence of physical fatigue, cognitive weariness, emotional exhaustion and burnout was calculated considering previous recommendation [20] to consider a cut-off value of five, or higher, as indicator of problems in a specific domain. Statistical significance was set at $p \leq 0.05$.

3 Results

Seventy-one physiotherapists returned their questionnaires, 88.7% (n = 63) females and 11.3% (n = 8) males. This gender imbalance discouraged between gender analysis. The descriptive statistics (median and interquartile range) and the Spearman correlation coefficients between the assessed variables are presented in Table 1.

Significant associations were found between the subscales of SMBM and the global burnout score (0.764 < Spearman's rho < 0.904). Cognitive weariness evidenced a very high positive correlation with the global burnout score and physical

Table 1 Correlation matrix for the studied variables and descriptive statistics

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) Physical fatigue	–							
(2) Cognitive weariness	0.665**	–						
(3) Emotional exhaustion	0.441**	0.631**	–					
(4) Burnout, global	0.822**	0.904**	0.764**	–				
(5) Age (years)	0.108	0.077	0.270*	0.168	–			
(6) Clinical experience	0.198	0.146	0.336**	0.249*	0.910**	–		
(7) Number of patients/day	0.372**	0.198	0.192	0.335**	0.135	0.156	–	
(8) Number of hours/day	0.298**	0.102	0.134	0.248**	0.095	0.169	0.505**	–
Median	3.83	2.00	1.33	2.19	30.00	8.00	30.00	8.00
IQR	2.33	2.20	1.00	2.60	6.00	6.00	10.00	1.00

Note IQR: interquartile range; $*p < 0.05$; $**p < 0.01$

fatigue and emotional exhaustion evidenced high positive correlation with the burnout score.

Age was only significantly correlated with emotional exhaustion, but the association was very weak. Clinical experience evidenced a weak association with the global score of burnout and a low positive association with emotional exhaustion. The number of patients treated daily evidenced a low positive association with physical fatigue and global score of burnout, and the number of daily working hours evidenced a very weak association with physical fatigue and with the global score of burnout.

Comparing the groups formed based on workload, no significant differences were found for age ($p = 0.07$) and clinical experience ($p = 0.06$), but significant differences were found for the number of patients treated daily ($p < 0.001$) and for the number of daily working hours ($p < 0.001$) (Fig. 1). The group with higher workload reported treating a median number of 34 patients and working a median of 8 h per day and the group with lower workload reported treating a median number of 20 patients and working a median of 6.75 h per day.

Regarding burnout and its dimensions, the group with higher workload reported a median of 4.00 in physical fatigue, a median of 2.40 in cognitive weariness, a median of 1.33 in emotional exhaustion and a median of 2.44 in the global burnout score. The group with lower workload reported a median of 2.75 in physical

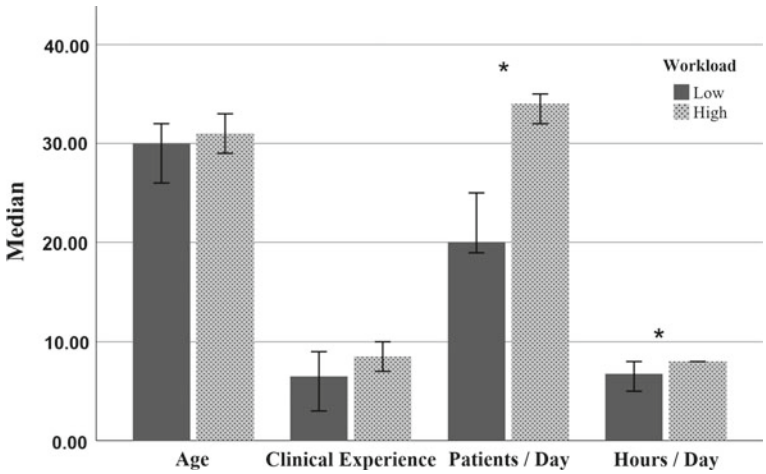

Fig. 1 Between group comparison for age (years), clinical experience (years), number of treated patients daily (number of patients) and daily working hours (hours)

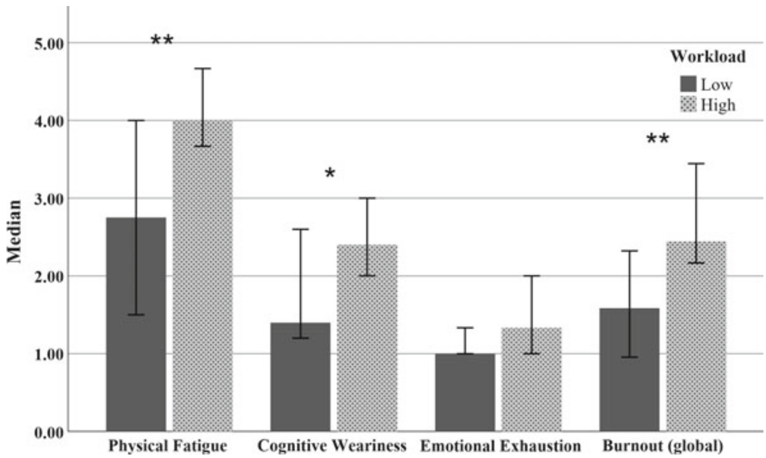

Fig. 2 Between group comparison for the scores of physical fatigue, cognitive weariness, emotional exhaustion and global burnout

fatigue, a median of 1.40 in cognitive weariness, a median of 1.00 in emotional exhaustion and a median of 1.58 in the global burnout score. Significant differences were found for physical fatigue (p = 0.003), cognitive weariness (p = 0.048) and global burnout score (p = 0.003) (Fig. 2).

The prevalence of burnout was 15.5% for the global burnout score (8.3% in the low workload group vs. 19.1% in the high workload group), 19.7% for the physical fatigue domain (4.2% in the low workload group vs. 27.7% in the high workload group), 12.7% for the cognitive weariness domain (8.3% in the low workload group vs. 14.9% in the high workload group), and 2.8% for the emotional exhaustion domain (0% in the low workload group vs. 4.3% in the high workload group).

4 Discussion

The prevalence of burnout among Portuguese physiotherapists was not very high, 15.5% for the global burnout score, 19.7% for the physical fatigue domain, 12.7% for the cognitive weariness domain and only 2.8% for the emotional exhaustion domain. Although not very high, these prevalence values indicate that these professionals are at risk and attention should be paid to the variables related to the phenomenon, especially workload since physiotherapists with high workload evidenced higher prevalence values in all scores, 19.1% in global burnout score, 27.7% in physical fatigue, 14.9% in cognitive weariness and 4.3% in emotional exhaustion.

The results of this study are in line with previous research stating that the prevalence of burnout in Portuguese physiotherapists was not high [17]. However, the prevalence of emotional exhaustion in that study was 31%, a much higher value than the 2.8% reported in the current study. These differences may be explained by the fact that a different instrument was used to assess the domain and by the fact that the sample in the study of Rodrigues and colleagues [17] had different characteristics regarding age, professional experience and size. However, the proportion of females was much higher in our study and females have been associated with higher levels of emotional exhaustion than males [21], therefore, higher levels of emotional exhaustion were expected. In other studies, addressing the thematic of burnout in physiotherapists, the reported prevalence for burnout is variable. Gisbert et al. [18] reported that only 4% of the surveyed Spanish physiotherapists reported burnout. Bruschini et al. [11] have reported that 15.7% of the surveyed Italian physiotherapists are at high risk of developing burnout, Śliwiński et al. [16] reported that 22.5% of the surveyed Polish physiotherapists evidenced high levels of burnout and Schuster et al. [22] reported a prevalence of burnout of 53% in American physiotherapists. Moreover, emotional exhaustion was the burnout domain most consistently reported as the most prominent in physiotherapists, but not in our study, which reported physical fatigue as the most affected burnout domain, followed by cognitive weariness. Interestingly, cognitive weariness was strongly associated with the global burnout score, more than any of the other domains. The distinct cultural background of the physiotherapists enrolled may help explain the differences in findings regarding prevalence of burnout and emotional exhaustion.

Age was weakly associated with emotional exhaustion but not with total burnout score. This is partially in line with the literature that often reports no association between burnout and age [23, 24], however, other studies, although not testing directly for the association between age and burnout, report that burnout prevalence is higher in physiotherapists aged 46–62 years and lower in physiotherapists aged 21–35 years.

Clinical experience evidenced a weak positive association with the global score of burnout and a low positive association with emotional exhaustion. This trend is the opposite of what has been reported in the literature. Śliwiński et al. [16] reported that physiotherapists with 5–15 years of service are prone to experience burnout with age but not on the other length of service categories and Schlenz et al. [25] stated that emotional exhaustion scores have a significant inverse relationship with years of experience at the present job. Wandling, Smith [12] also suggest that burnout is lower in physiotherapists working for more than 16 years. In our study the prevalence of physical fatigue was moderate. This domain is assessed by the SMBM but not by the instruments used to assess burnout in the cited studies. In our sample, physical fatigue was the most prominent burnout domain and we also showed that workload is associated with burnout. Therefore, we argue that more years exposed to high levels of workload and physical fatigue are responsible by the association between clinical experience and burnout.

The physical fatigue, cognitive weariness and global burnout scores were higher in physiotherapists with higher workload. This is reinforced by the significant association between daily working hours and number of patients treated and physical fatigue and global burnout scores. This is in line with previous studies that also found higher burnout in physiotherapists working more than 40 h per week directly with patients and in those treating more than 20 patients per day [23].

This study has some limitations, namely the small sample size and the imbalance between males and female participants that limited the data analysis. Another limitation is the fact that the coping strategies employed by the physiotherapists to deal with physical, cognitive and emotional strain have not been addressed.

5 Conclusion

The prevalence of physical fatigue, cognitive weariness, emotional exhaustion and global burnout in Portuguese physiotherapists was 19.7, 12.7, 2.8 and 15.5%, respectively. These professionals are involved in attaining the patient goals, living their successes and their failures. Hence, the physical, cognitive and emotional load is high. Workload plays a key role in the process and health care managers should focus on prevention and early detection to help professionals improve their resilience. More studies are needed on this topic and should investigate the strategies adopted by health professionals, in general and physiotherapists in particular, to cope with burnout.

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Psychological Distress on Nurses: The Role of Personal and Professional Characteristics

Clara Simães and A. Rui Gomes

Abstract This study explored the role of nurses' personal and professional characteristics on the expression of psychological distress, overcoming the limitations of studying humans' responses to work environments using the stress-strain approach. The sample consisted of 2203 registered nurses working in Portugal. The investigation protocol included a Sociodemographic and Professional Questionnaire and the Portuguese version of the General Health Questionnaire-12. A high percentage of nurses (79.3%) showed levels of psychological distress, deserving for clinical attention. Significant differences were found between nurses with and without clinical symptoms of psychological distress. Female nurses, those working in primary health care, and nurses with no hobby and no physical exercise behaviors, presented significant levels of distress, deserving for clinical attention. These nurses reported high levels of anxiety/depression and social dysfunction. More, the absence of a hobby and the lack of physical exercise behaviors constituted as risk factors for the experience of clinical symptoms of distress, anxiety/depression and social dysfunction. These findings represent an important issue in occupational stress research, suggesting that leisure activities may be a protective factor for nurses' mental health, acting as a "Daily Uplifts" for the stress recovery balance. Thus, in order to ensure the patients' safety and the quality of health care, health organizations must consider nurses' personal and professional characteristics that influence their mental health and global functioning when developing occupational health programs.

Keywords Nurses · Occupational stress · Psychological distress

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1 Introduction

Occupational stress in health professionals has become a matter of public health, due to its negative effects on individuals' mental health, in such a way that job stress has been called for many the "plague of the century" [1]. Research has been pointing special attention for nurses, as a professional group continuously exposed to worrying levels of stress, in their work environment [2].

Nursing professionals have to face several hard burdens related to the nature of health care and work environments, characterized by high psychological, physical and emotional demands, allied to a reduced degree of control and rewards. In fact, nurses constitute the professional group with the closest relationship to patients and families, and have to deal constantly with life threatening events and adversity [3]. Moreover, the work in health care has been subject to an economic crisis, which seeks for profit in health organizations, with consecutive and dramatic budgetary cuts, in terms of human and material resources, resulting in considerable physical and emotional overload for nurses. Specifically, nurses had to face an increase of the patients' ratio per nurse per shift; an extension of the working period and working overtime, often unpaid; an increase in shifts with irregular patterns; insecurity in the working conditions; precarious employment contracts and the lack of career progression [3]. These sources of occupational stress, allied to a huge responsibility, low decision-making, irregular shift work, night shifts, high number of working hours per shift, workload, reduced salary and lack of recognition, are frequently perceived as surpassing the individuals' personal resources, and resulting in a negative adaptation to stress [4]. An important outcome of the negative adaptation process is the deterioration of the individuals' mental health and the expression of psychological distress, which in turn, affects the quality of health care, the organizational climate and productivity [1, 5].

Being nursing professionals highly vulnerable to the effects of occupational stress, nurses' psychological health is of a huge relevance in terms of occupational safety, due to its clinical power and effect on the person's health, functioning and safety [5, 6]. In detail, psychological distress has been conceptualized "as a negative state of mental health characterized by anxiety and depressive symptoms" [6], which can be viewed as an emotional disturbance that may impact social functioning and day-to-day living of individuals. Moreover, psychological distress can constitute a diagnostic criterion for some psychiatric disorders (e.g., post-traumatic stress disorder) or even as a marker of the symptoms' severity in other disorders (e.g., generalized anxiety disorder) when accompanied by impairment in daily living [7].

Studies on occupational stress, in health professionals, has shown to be valuable in predicting health outcomes, namely psychological distress [1, 5]. However, it has been too centered in studying the effect of psychosocial work characteristics [2, 8], based on several occupational stress models and in the study of humans' responses to work environments using the stress-strain approach [5]. This approach tends to simplify a phenomenon that is dynamic and individualized, buffering minor sources of stress, as the "daily hassles" [4], thus, disregarding the role of nurses' personal and professional characteristics. Therefore, surpassing the restrictions of the stress-strain approach, in this study we sought to explore the role of personal and professional variables on nurses' psychological distress. To do so, we established three main goals:

(1) Explore the relation between the personal and professional variables and psychological distress in nurses;
(2) Identify risk factors for clinical symptoms of psychological distress;
(3) Identify risk factors for anxiety/depression and social dysfunction in nurses.

2 Method

2.1 Participants

A convenience sample of 2203 registered nurses, working in Portugal, was assessed through an online platform. With a mean age of 33.7 (SD = 9.39) years old, 82.1% of the nurses were female and 42.5% were married. Most of the nurses belonged to the institutional staff board (69.6%), 57% were working in a hospital, and 64.4% worked by shifts. Moreover, 50.9% of the nurses reported not accomplish any type of physical exercise, nor having any hobby (27.9%).

2.2 Procedure

The research embraces a descriptive correlational cross-sectional study design. The study used an online questionnaire of self-reported measures, which was sent to all nurses working in Portugal, through the Professional Association network, inviting them to anonymously and voluntarily participate in the study. The study was conducted in harmony with the National and European regulations of research with humans.

3 Measures

Sociodemographic and Professional Questionnaire. It was based on previous studies of occupational stress in health professionals [1, 9, 10], evaluating personal (age, gender, marital status, education level, hobby, physical exercise) and professional (type of workplace, clinical specialty, professional category, type of contract, shift work, years in the profession, number of working hours, absenteeism) characteristics of nurses.

General Health Questionnaire-12 [GHQ-12; 11]. Measures the individuals' general psychological health and changes in affective and somatic symptoms relative to the usual levels of health [1, 12, 13]. In this study, we used the Portuguese version of the GHQ-12 [8], to assess nurses' psychological distress (e.g., severity of psychological distress; anxiety/depression, and social dysfunction). The instrument contains 12 items, where participants report how often they experience a specific symptom (1 = better than usual; to 4 = much less than usual). This study considered both the total value of the scale (12 items; $\alpha = .82$) and the two subscales: (a) anxiety/depression (six items; $\alpha = .82$); and (b) social dysfunction (six items; $\alpha = .76$). Confirmatory factor analysis showed an acceptable fit [14] for a two-factor model: $\chi^2(49\ \mathrm{df}) = 205.31$, $\chi^2/\mathrm{df} = 4.19$, $p < .001$; RMSEA = .037, $p(\mathrm{RMSEA} \leq .05) = 0.99$, 90% C.I. [.032, .043]; NFI = .974; TLI = .973; CFI = .980; GFI = .985.

3.1 Data Analysis

Data analysis was completed through IBM SPSS and AMOS Program (version 25). An exploratory data analysis revealed that the assumptions for using parametric tests were met, so we proceed with the statistical tests, assuming a 95% C.I., rejecting the null hypothesis for a p-value < .05. Regarding the severity of psychological distress, by using the GHQ-12 cut-off threshold 2/3, as indicated in the manual [13] and in previous studies [1], we constituted two groups: with and without clinical symptoms of psychological distress. After these procedures, we tested the relation between the personal (age, gender, marital status, education level, hobby, physical exercise) and professional variables (type of workplace, clinical specialty, professional category, type of contract, shift work, years in the profession, number of working hours, absenteeism) and the dependent variables (severity of psychological distress; anxiety/depression; and social dysfunction) (study goal 1). Second, we performed a logistic regression analysis in order to identify risk factors for the clinical symptoms of psychological distress (study goal 2). Finally, we conducted a hierarchical linear regression analysis in order to identify risk factors for anxiety/depression and social dysfunction (study goal 3). The entrance of the variables followed previous indication of literature on occupational stress on nurses [9], according to the following steps: (1) in the first step, we introduced personal variables concerning sociodemographic characteristics (age, gender and marital status); (2) in the second step, we introduced personal variables concerning life style (hobby and physical exercise); and, (3) in the last step, we introduced professional variables (type of workplace). Type of workplace was divided on two groups (hospital and primary health care), as it seems to be an important variable in order to understand nurses' work environment [9, 10].

4 Results

4.1 Personal and Professional Characteristics and Psychological Distress

This section aims to explore the relation between nurses' personal and professional characteristics and psychological distress (study goal 1).

Severity of psychological distress: nurses with and without clinical symptoms. Regarding the total sample, the overall prevalence of psychological distress (M = 5.31, SD = 2.94) was higher to that reported in the literature [1], and more pronounced in anxiety/depression, compared to social dysfunction (see Table 1). Using the GHQ-12 cut off 2/3 for clinical cases [1, 13], 79.3% of the nurses showed clinical symptoms of psychological distress. Nurses with clinical symptoms showed a worse psychological profile, reporting more anxiety/depression (t = −60.99, $p < .001$) and social dysfunction (t = −17.47, $p < .001$), than nurses' without clinical symptoms. These results are presented in Table 1.

Personal characteristics. Significant differences were found between nurses with and without clinical symptoms in terms of gender, hobby, and physical exercise. Aside the highest age (t = −1.86, $p = .063$), we found more clinical cases in women, rather than in men ($\chi^2_{(1)} = 4.49, p = .034$). On the contrary, we found a higher incidence of nurses without clinical symptoms among those that reported having a hobby ($\chi^2_{(1)} = 12.62, p < .001$) and performed physical exercise ($\chi^2_{(1)} = 19,75, p < .001$).

Professional characteristics. The incidence of clinical cases was not independent from the type of workplace ($\chi^2_{(1)} = 5.16, p = .023$). A higher percentage of cases without clinical symptoms was observed in nurses that worked in the hospital setting.

Anxiety/depression and social dysfunction. A MANOVA showed significant differences in anxiety/depression and in social dysfunction, in relation to marital status (Wilks' $\lambda = .999$, $F_{(2, 1955)} = 3.45$, $p = .032$, $\eta p2 = .004$; $\pi = .746$); having a hobby (Wilks' $\lambda = .994$, $F_{(2, 1955)} = 3.92$, $p = .003$, $\eta p2 = .006$; $\pi = .878$); and the type of professional contract (Wilks' $\lambda = .993$, $F_{(2, 1577)} = 5.37$, $p = .005$, $\eta p2 = .007$; $\pi = .843$). Despite the small effect size ($\eta p2 \leq .05$), the observed power of the tests was large ($\pi \geq .8$; [14]). The univariate tests showed that anxiety/depression was significantly higher in nurses with no hobby (M = 4.39, SD = .19), compared to those who had a hobby (M = 3.95 , SD = .06; $F_{(1)} = 4.79$, $p = .029$). However, social dysfunction was significantly higher in nurses that were single (M = 1.45, SD = .13; $F_{(1)} = 6.86$, $p = .009$); that had no hobby (M = 1.50, SD = .15; $F_{(1)} = 10.52$, $p = .001$), and that held a permanent type of professional contract (M = 1.76, SD = .11; $F_{(1)} = 10.34$, $p = .001$). In comparison to nurses that were married (M = 1.02, SD = .10), had a hobby (M = 0.97, SD = .05), and, that held a precarious type of contract (M = 0. 80, SD = .21).

Table 1 Significant differences between the Clinical and Non-Clinical groups of nurses, on the personal and professional variables, and psychological measures (N = 2203)

Nurses characteristics	Total sample (N = 2203)	Non-clinical group (n = 456, 20.7%)	Clinical group (n = 1747, 79.3%)	*p*
Personal variables				
Age (y) M(SD)	33.7 (9.39)	32.9 (9.24)	33.9 (9.43)	.063
Gender				
Male	394 (17.9)	97 (21.3)	297 (17.0)	.034
Female	1809 (82.1)	359 (78.7)	1450 (83.0)	
Hobby				
Yes	1588 (72.1)	359 (78.7)	1229 (70.3)	<.001
No	615 (27.9)	97 (21.3%)	518 (29.7)	
Physical exercise				
Yes	1081 (49.1)	266 (58.3)	815 (46.7)	<.001
No	1122 (50.9)	190 (41.7)	932 (53.3)	
Professional variables				
Type of workplace				
Hospital	1255 (56.9)	268 (82.7)	987 (76.9)	.023
Primary health care	353 (16.0)	56 (17.3)	297 (23.1)	
Psychological variables				
GHQ-total M(SD)	5.31 (2.94)	1.16 (0.79)	6.40 (2.25)	<.001
$GHQ_{(Anxiety/Depression)}$ M(SD)	4.11 (1.97)	1.04 (0.78)	4.91 (1.29)	<.001
$GHQ_{(Social\ Dysfunction)}$ M(SD)	1.20 (1.59)	0.11 (0.33)	1.49 (1.67)	<.001

Note Continuous variables are presented as M (SD); categorical variables are presented as n (%). y = years, GHQ = General Health Questionnaire

4.2 *Risk Factors for Clinical Symptoms of Psychological Distress*

To identify personal and professional risk factors associated to clinical symptoms of psychological distress (study goal 2) we conducted a logistic regression analysis (Table 2). The Hosmer-Lemeshow Chi2 statistic (χ^2HL(6) = 3.17, p = .79) indicated a well-fitted model [14]. The model tested was significant in predicting clinical symptoms, and allowed to classify correctly an overall percentage of 79.9% of the cases. Having no hobby, no physical exercise behaviors, and working in primary health care, was related to greater clinical symptoms of psychological distress.

Table 2 Logistic regression analysis for predictors of clinical symptoms of distress (N = 2203)

Predictors for clinical symptoms (GHQ-12)	B	Wald	Odds ratio [95% CI]	*p*
Step1				
Gender[a]	−.295	3.588	.745 [.549, 1.010]	.058
Step 2				
Hobby[b]	−.371	5.392	.690 [.505, .944]	.020
Physical exercise[c]	−.342	6.459	.711 [.546, .925]	.011
Step 3 (Final Model)				
Gender[a]	−.190	1.438	.827 [.607, 1.128]	.230
Hobby[b]	−0.364	5.196	.695 [.508, .950]	.023
Physical exercise[c]	−.336	6.254	.714 [.549, .930]	.012
Type of workplace[d]	−.327	4.052	.721 [.525, .991]	.044
$\%_{\textbf{Corrected}}$ = 79.9; ($\chi^2_{(4)} = 26.561; p \leq .001$)				

Note [a]Dichotomous variable: 0 = female, 1 = male; [b]Dichotomous variable: 0 = no, 1 = yes; [c]Dichotomous variable: 0 = no, 1 = yes; [d]Dichotomous variable: 0 = primary health care, 1 = hospital

4.3 Risk Factors for Anxiety/Depression and Social Dysfunction

To identify personal and professional risk factors for anxiety/depression and social dysfunction (study goal 3), we accomplished a hierarchical linear regression analysis (Table 3). Findings revealed that more age, having no hobby, and no physical exercise behaviors was associated to higher levels of anxiety/depression. In addition, being single and having no hobby was related to greater social dysfunction.

5 Discussion

The present study explored the role of personal and professional variables on nurses' psychological distress. In order to do so, we formulated three main goals.

Regarding the first goal, results revealed significant differences between nurses with and without clinical symptoms of psychological distress. Older and female nurses, with no hobby, and no physical exercise behaviors, working in primary health care, were more likely to present clinical symptoms of distress. More, nurses with clinical symptoms showed a worse psychological profile, expressing more anxiety/depression and social dysfunction. Still, the experience of anxiety/depression was significantly higher in nurses with no hobby, but social dysfunction was greater in single nurses and in those with a permanent/full type of contract. These results are in line with research [1, 7] reporting that women and single

Table 3 Hierarchical linear regression analysis for predictors of anxiety/depression and social dysfunction (N = 2203)

Results/predictors	ΔR^2	ΔF	β	t
Anxiety/Depression (GHQ-12)				
Step1	.002	4.487*		
Age[a]			.046	2.184*
Step2	.014	15.949***		
Hobby[b]			.074	3.264***
Physical exercise[c]			.071	3.133**
R^2 = .016; $R^2_{Adjusted}$ = .015; $F_{(3,2227)}$ = 12.149***				
Social Dysfunction (GHQ-12)				
Step1	.001	2.633		
Marital Status[d]			−.059	−2.711**
Step2	.036	77.336***		
Hobby[b]			.192	8.794***
R^2= .038; $R^2_{Adjusted}$= .037; $F_{(2,2042)}$ = 40.030***				

Note [a]Continuous variable, in years; [b]Dichotomous variable: 0 = yes, 1 = no; [c]Dichotomous variable: 0 = yes, 1 = no; [d]Dichotomous variable: 0 = not married, 1 = married. *p < .05. **p ≤ .01. ***p ≤ .001

workers show more tendency to experience problems related to work stress. This pattern is strongly associated to changes in employment status, marital status, and education across adulthood, which must be established as a required framework to research analysis [7], underlining the importance of considering a developmental perspective across the lifespan [15]. Thus, older nurses and those with a permanent/full contract can face serious difficulties in developing new coping strategies to adapt to unexpected living conditions (e.g., cuts in salaries; contractual restructuring), resulting in significant levels of distress.

Concerning the second goal, findings showed that working in primary healthcare, having no hobby and no physical exercise behaviors, constitute risk factors for clinical symptoms of distress. Hospital settings are known for its adversity [3, 5], so, it would be expected that hospital nurses showed a higher risk of experiencing psychological distress, and not primary health care nurses. These results can be understood in the light of the role of the family nurse, which implies a broader and demanding field of action and specialization that should be considered by health organizations.

Regarding the third goal, results showed that being single and having no hobby constitute risk factors for social dysfunction; while being older, having no hobby and no physical exercise behaviors constitute risk factors for anxiety/depression. Indeed, little is known about nurses lifestyle and leisure activities, as shown by a recent systematic review [16], emphasizing the paucity of research on nurses' health behaviors. Thus, in this study, aside the classical sociodemographic variables, we explored the role of leisure activities on nurses' distress, showing that these variables produced independent positive effects on nurses' psychological health. This represent an important issue in occupational stress research, pointing for the leisure activities as a protective factor for nurses' mental health, acting as the "daily uplifts" [17] for the stress recovery balance [18]. Although that, it is also important to consider the reverse chain. The experience of psychological distress, as an outcome of occupational stress, can lead to significant changes in nurses' daily living, resulting in the lack of leisure activities (e.g., exercise). Thus, in order to ensure the patients' safety and the quality of health care, health organizations must consider nurses' characteristics that are related to their mental health and global functioning when developing occupational health programs. Findings point for a professional group that requires reflection and consideration, in terms of occupational stress intervention, highlighting the role of leisure activities for nurses' mental health, giving support to the need of healthy life styles, which must be promoted by health organizations to attain occupational safety.

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Adaptation and Validation of the Work-Family Conflict and Family-Work Conflict Scales in Portuguese Nurses: 10-Item Version

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Abstract This study presents the adaptation and validation of a Portuguese version of the Work-Family Conflict and Family-Work Conflict scales for nurses. Participants were 310 female hospital-based nurses, from the northern region of Portugal. The assessment protocol included the Portuguese 10-item Work-Family Conflict and Family-Work Conflict scales to measure the mutual interference of the work and home domains. The Portuguese version resulted from a multi-step adaptation strategy, involving direct-translation, back-translation and a pre-test. Construct validity was assessed by exploratory principal components factor analysis and confirmatory analysis. The internal consistency reliability was calculated using Cronbach Alpha coefficients. The Cronbach Alpha coefficients for the Work-Family Conflict and Family-Work Conflict (0.91 and 0.85 respectively) indicate good reliability. The factor analysis produced two factors, explaining 69.3% of the variance, replicating the model proposed by the original authors. The confirmatory factor analysis showed a good model fit (NFI, TLI and CFI values >0.950). The RMSEA (<0.05) provided a good measure of the closeness of fit between the model and the data. The Portuguese version of the Work-Family Conflict and Family-Work Conflict scales shows good validity and reliability.

Keywords Female nurses · Work-family conflict · Family-work conflict

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1 Introduction

Research in Occupational Health Psychology has identified the mutual interference between work and family domains as one of the ten major sources of occupational stress [1]. This construct is especially important for nursing professionals, in particular for hospital-based nurses, mainly due to the extended work hours (12 h or longer), the irregular work schedules, overtime, and the high workload demands [2].

The mutual interference concerning work and family life, has shown to be significantly associated with several health and professional outcomes [2, 3]. Specific outcomes include, reduced organizational commitment [4], poorer job performance [5], job and life dissatisfaction, lower family satisfaction, greater psychological distress [6], high levels of burnout, emotional exhaustion and cynicism [4], insufficient sleep and sleep disturbances [2], substance abuse, depression and somatic symptoms [5]. The notion of work-family and family-work conflict is based on the premise that role expectations in the areas of work and family are not always compatible, thereby producing conflict between an individuals' family and work experience [7]. Consequently, work can interfere with a person's private life, resulting in a form of "work-to-family conflict" (WFC) and/or, family life can interfere with subject's work performance, resulting in a form of "family-to-work conflict" (FWC) [8, 9]. Although related, these forms of inter-role conflict are assumed to be distinct constructs [7–9].

Work-to-family conflict (WFC) can be defined as "a form of inter-role conflict in which, the general demands of, time devoted to, and the strain created by the job, interfere with performing family-related responsibilities", while family-to-work conflict is considered to be "a form of inter-role conflict in which the general demands of, time devoted to, and the strain created by the family interfere with performing work-related responsibilities" [7, p. 401]. In order to assess these two constructs, the authors developed a 10 item self-report questionnaire, consisting of two scales, the work-family conflict and family-work conflict scales (WFC & FWC scales) [7]. The scales have presented good reliability and validity properties [7, 10], and have been widely used to assess WFC and FWC in a variety of professions [e.g., Fuss et al. 10]. In a European study on registered nurses [1], involving eight countries from the longitudinal European NEXT-Study (Belgium, Finland, France, Germany, Italy, Netherlands, Poland, and Slovakia), the WFC and FWC were studied, using the instrument developed by Netemeyer and colleagues [7]. Findings from this study indicated that the Cronbach's alpha for WFC ranged from 0.86 (France and Italy) to 0.90 (Finland), and for FWC from 0.73 (Belgium and Slovakia) to 0.87 (Netherlands) [1], showing a good internal consistency reliability for these scales [11]. Results also demonstrated a higher incidence of WFC in comparison to FWC, in all European countries, highlighting the importance of nurses' working conditions. Although the conflict between family and work, and work and family, is quite well-known in the nursing profession [1], research in this area has been scarce in Portugal and no valid instruments which focus on WFC and FWC exist to study this phenomenon in Portuguese nursing professionals. Thus, the aim of this paper is to present the validation study of the Portuguese adaptation of the Work-Family Conflict and Family-Work Conflict scales [7] in a sample of hospital-based nurses. The psychometric properties of the Portuguese version of the scales were examined in terms of reliability and construct validity. Although not a primary goal of this study, the results of this validation will also shed light on the cross-cultural generalizability of this construct in a family-oriented southern European culture, which is likely to impact the experience and level of WFC and FWC.

2 Method

2.1 Participants

A stratified random sample of 310 female hospital-based registered nurses was used for this study. Participants worked in four public central hospitals that were part of the northern Portuguese regional health administration. The mean age was 33.83 (SD = 8.70) years old. Nearly 12% (n = 36) of nurses had a postgraduate degree, 161 (51.9%) were married, and 71 (22.9%) had partners with shift-working jobs. In this sample, 130 nurses (41.9%) had the major household responsibilities, 135 (43.5%) were mothers and 55 (17.7%) were the main source of the family's income. Most of the nurses (78%), worked in general medicine, surgical units, emergency, cardiology, and pediatrics. The mean of years in the profession was 11.38 (SD = 8.64). The mean for daily work hours was 8.27 (SD = 2.22, range 4–19 h) and the mean for work hours per week was 37.03 (SD = 2.90, range 25–45 h). In this sample, 149 (48.1%) nurses had a precarious contract, 243 (78.4%) worked by shifts, and 91 (29.4%) had a second job, with an average of 14.92 (SD = 7.26) work hours per week. In this last group of nurses with a second job, the mean was 52 h per week.

2.2 Measures

The assessment protocol included a sociodemographic questionnaire and the Portuguese versions of the following instruments: (a) the Work-Family Conflict and Family-Work Conflict Scales [WFC&FWCs, 7]; (b) the General Health Questionnaire-12 [GHQ-12, 12], and the Brief Personal Survey-Revised [BPS-R, 13].

The Work-Family Conflict and Family-Work Conflict Scale is a 10 item self-report questionnaire that assesses work-to-family conflict and family-to-work conflict. As in the original instrument [7], the Portuguese version developed by the authors, consists of 10 items, which are intended to measure the degree of interference between work and family domains, and vice versa. Participants are requested to indicate on a 7-point Likert scale (1 = strongly disagree, to 7 = strongly agree), to what extent they agree or disagree with each statement presented (e.g., "the demands of my work interfere with my home life"). According to Netemeyer and colleagues [7], the degree of the mutual interference between work and family lives results from the sum of the scores obtained in each of the 10 items, ranging between 10 and 70, in such a way that higher values signify a substantial amount of perceived mutual interference between the two domains. However, in emphasizing the multidimensionality of the instrument, it is possible to calculate separately the perceived interference of one's own work in family life (WFC), and the degree of negative intrusion of the family domain to the work setting (FWC). This calculation corresponds to the two scales proposed by the authors, respectively, resulting from the sum of the scores in the first five items, for the WFC scale, and the sum of the scores in the last five items, to scale the FWC. Thus, the score of each scale ranges from 5 to 35, with higher values pointing to a greater awareness of interference from one area to another [7].

The General Health Questionnaire-12 has been used to conduct stress audits in occupational studies with the goal of assessing the prevalence of psychological morbidity and to differentiate clinical cases from non-clinical, namely in health professionals [14]. The GHQ-12 is a widely used and validated scale, translated into several languages, and shows good internal consistency with Cronbach's alpha values ranging between 0.80 and 0.90 [15]. In this study, we used the Portuguese version of the GHQ-12, adapted by McIntyre, McIntyre and Redondo. The instrument comprises 12 items, in which the subject is asked to expresses how he/she has been feeling, or how he/she has perceived his/her own health, for the last few weeks. The response format is a four categories Likert scale (1 = better than usual, to 4 = much less than usual). To score the GHQ-12, we used the dichotomous scale (0-0-1-1) and the cut-off point 2/3 (at least three symptoms reported) [14, 16]. According to the authors, a value equal or greater than 3 is an indicator of psychological morbidity representing distress levels that deserve clinical attention [14]. The higher the total value of the scale, the worse the subject's mental state [15]. In this study, the univariate solution showed good internal consistency (with Cronbach's alpha of 0.79).

The Brief Personal Survey [13] was specifically designed to be used in health settings, and is made up by several scales for screening health professional's stress responses and general coping resources used in confronting stressful situations [17]. The instrument has been showing good psychometric properties in terms of validity and reliability [17]. In this study, we used a revised version [BPS-R]. This is a self-report questionnaire, which includes eight scales and three "critical indexes", consisting in 57 items, formulated in the present tense. Responders were asked to indicate whether each statement applies, or not, to their situation, using a dichotomous type of response (true or false; 1 or 0), as the statement is applicable or not. The total scale score results from the sum of the respective items. We used the stress response scales denial, pressure overload and guilt. The psychometric properties of the BPS-R in this study showed Cronbach's alpha values of 0.61 for guilt, 0.62 for pressure/overload, and 0.50 for denial, which warrants caution in the interpretation of these results. The data confirmed the factorial structure of the original version of the instrument.

2.3 Procedure

Data were collected from several health units consisting of 10 different medical specialties, from four Portuguese Hospitals. Each participant had to have been in the hospital nursing profession for at least one year. Participation was anonymous and voluntary written consent was obtained from all participants. The research protocol was distributed to the participants by the service supervisor so as to not disturb the normal functioning of each health unit. The self-report questionnaires were returned to the supervisor in closed envelopes and were later collected by the researcher. The total response rate was 51.66% or 310 nurses of the 600 nurses recruited. This is in line with the response rate reported in the literature for female samples where non-compliance rates range between 35% and 67% [e.g., Hobfoll et al. 18]. The Portuguese experimental version of the WFC&FWCs, developed specifically for this study, followed the method of direct and reverse translation from the original version into Portuguese. A pre-test of the instrument was done on a sample of 50 hospital nurses. The nurses gave feedback on the translation of the items and adaptations were made to the items based on this feedback. This ensured that the translation is appropriate to the nursing professionals. The revised translation, based on the pre-test feedback, was subsequently reverse translated from Portuguese into English by qualified bi-lingual speakers. The translated and reverse translated versions were then compared in order to verify discrepancies and make corrections [19].

2.4 Data Analysis

Exploratory data analysis showed that, for the majority of the variables, the assumptions for using parametric tests were met. Construct validity was assessed by exploratory principal components factor analysis and confirmatory factor analysis. The internal consistency reliability was calculated using Cronbach's Alpha Coefficients [11]. Statistical tests were carried out using IBM SPSS Statistics and AMOS (version 24).

3 Results

3.1 *Psychometric Properties of the Portuguese Version of WFC&FWC Scales*

Construct Validity of the Exploratory Version. The conceptual structure of the Portuguese version of the scales was achieved by replicating the proceedings described in the original study [7]. A principal components factor analysis of items was done, without previous definition of the number of factors, using varimax rotation and eigenvalue ≥ 1. The Kaiser-Meyer-Olkin index (KMO $\geq$ 0.6) and the Bartlett's test ($p < 0.05$) indicated the sample's adequacy for this procedure [11] (KMO = 0.842; TEB = 1849.70, $p < 0.001$), meaning that correlation matrix was not an identity one and factor analysis was able to be carried out. The exploratory factor analysis demonstrated that the items of the instrument, are organized by two dimensions, in agreement with the original model [7]. Together, the two factors explain 69.3% of the total variance found in this study. After rotation, factor I, was composed of the first five items (1, 2, 3, 4, 5), concerning work-to-family conflict matters, and justifies 37.6% of the overall founded variance. Factor II, was comprised of the last five items of the instrument (items: 6, 7, 8, 9, 10) related to family-to-work conflict issues, contributing with 31.7% of the total explained variance. All the items revealed factorial weights above 0.50 and were grouped in only one factor, with the exception of item 6, that despite weighing in both factors, revealed a higher weight in relation to factor II, as shown in Table 1. These data give support to the bi-dimensionality of this construct and the mutual interference of the work-family domains. Results for the construct validity of the WFC&FWCs are in Table 1.

Construct Validity of the Confirmatory Version. In order to achieve the final version of the WFC&FWC scales, confirmatory factor analysis was carried out, and attested the factor structure of the two large factors, obtained through the exploratory factor analysis (e.g., WFC and FWC), such as established in the original model [7]. Regarding the latent structure, the CFA showed that the model tested fit the data well. Specifically, the following tests of significance and goodness-of-fit measures were obtained: χ^2 (28df) = 32.60, $p = 0.251$, χ^2/df = 1.164; RMSEA = 0.023, 90% CI [0.001, 0.052], p (RMSEA $\leq$ 0.05) = 0.930; CFI = 0.997, NFI = 0.983, TLI = 0.996. As such, the probability level of χ^2 statistics was higher than 0.05, indicating a suitable fit. In terms of other goodness of fit indicators, the NFI, TLI and CFI, presented values superior to 0.95 showing a good model fit. Additionally the RMSEA being smaller than 0.05 provided a good measure of the closeness of fit between the model and the data. Therefore, the model can be considered adequate and valid [20].

Reliability for the WFC&FWC Scales. The reliability for the instrument showed that the Cronbach's Alpha Coefficients for the WFC component was 0.91, and for the FWC was 0.85. This indicates a good internal consistency reliability of these

Table 1 Construct validity and reliability results for the WFC&FWCs (N = 310)

Items	Factor load		Item-total correlation	α if item deleted
	FI	FII		
1. The demands of my work interfere with my home and family life	0.833		0.60	0.87
2. The amount of time my job takes up makes it difficult to fulfil family responsibilities	0.881		0.72	0.86
3. Things I want to do at home, are not done because of the demands my job puts on me	0.855		0.69	0.86
4. My job produces strain that makes it difficult to fulfil family duties	0.858		0.71	0.86
5. Due to work-related duties, I have to make changes to my plans for family activities	0.762		0.60	0.87
6. The demands of my family or spouse/partner interfere with work-related activities	0.417	0.594	0.61	0.87
7. I have to put off doing things at work because of demands on my time at home		0.822	0.56	0.87
8. Things I want to do at work are not done because of the demands of my family or spouse/partner		0.827	0.53	0.87
9. My home life interferes with my responsibilities at work such as getting to work on time, accomplishing daily tasks, and working overtime		0.809	0.47	0.88
10. Family-related strain interferes with my ability to perform job-related duties		0.822	0.51	0.87
Eigenvalues	3.76	3.17		
Total explained variance	69.3%			

Note [a]Orthogonal rotation, varimax method

scales [11]. For the total scale (WFC&FWC-total), which measures the global amount of work-family mutual interference, the Cronbach's Alpha was 0.88. These values are indicative of the good internal consistency reliability of the instrument, similarly to findings by the authors for the original version [7]. Table 1 also shows the item-total correlations and the Cronbach's Alpha Coefficient if item removed. The correlations of each item range between 0.47 and 0.72, showing that all items contribute significantly to the total measure. The findings replicate the alpha values found by the original authors of the instrument [7], and in a European study [1].

Discriminant Validity. In this sample, the mean value for WFC (M = 20.94, SD = 7.39, range 5–35) is superior to FWC (M = 11.47, SD = 5.87, range 5–31), representing a substantial global amount of work-family mutual interference (M = 32.43, SD = 11.15, range 10–63). These results are similar to those found in a cross-cultural study with nurses [1], suggesting that work interfering with family is more prevalent in Portuguese nurses, than family interfering with work. Additionally, as shown in Table 2, there is a significant positive association between the subscales WFC and FWC, and from these with WFC&FWC-total,

Table 2 Correlations for WFC&FWCs and stress responses (GHQ-12 and BPS-R) (N = 310)

	WFC&FWCs		GHQ-12	BPS-R		
WFC&FWCs	WFCs	FWCs	Distress	Denial	Pressure-overload	Guilt
WFCs	1	0.400***	0.363***	−0.163**	0.375***	0.248***
FWCs	0.400***	1	ns	ns	0.131*	0.265***
Total-scale	0.875***	0.794***	0.292***	−0.147*	0.321***	0.310***

Note $^{ns}p > 0.05$. $^{*}p < 0.05$. $^{**}p < 0.01$. $^{***}p < 0.001$

giving support to discriminant validity [7]. In addition, the total scale and the WFC subscale have a significant relationship with most of stress responses, measured by GHQ-12 and BPS-R, but the FWC subscale is only significantly associated with some stress responses. As such, higher FWC is associated with negative feelings of guilt and pressure overload while greater WFC is associated with less tendency to denial, but higher psychological distress and stronger feelings of guilt and pressure overload.

4 Discussion and Conclusions

Nursing professionals, being exposed to psychosocial as well as mechanical stressors at work, stand out as one of the occupational groups most affected by the mutual interference of work and family life. This is especially true for women that work in hospital settings [1]. However, despite the bidirectional interference of the home and the work domains being considered a relevant source of stress for female nurses, studies also reveal a greater prevalence for WFC in comparison to FWC [6]. Furthermore, the major predictors of stress indicated in these studies are job pressure and workload [3]. A WFC Model, developed in a European study with registered nurses [1], identified three main potential predictors for the WFC. First, the amount of time dedicated to work, in terms of work hours, shift schedules, and working overtime. Second, the strain created by work, explicitly by quantitative demands, emotional demands and leadership quality. Finally, individual factors, such as age and gender, showed women as more prone to experience WFC, than men.

Although WFC and FWC represent a relevant stressor in the workplace, especially for female nurses, only a few studies investigating work-home interference in nursing have been done. To our knowledge, there are no valid measures of the work-home interference for Portuguese nursing professionals. Thus, because of the lack of validated instruments in Portuguese, the decision was made to adapt and validate the Work-Family Conflict and Family-Work Conflict scales [7] into Portuguese, with a focus on hospital nurses. Findings from this study showed a mean value for WFC superior to that found for FWC, which is comparable to that reported in a European study with nurses, involving several countries using the same scales [1]. These results support the relevance of studying work-family interference in Portuguese nurses and developing appropriate measures for this context. Results from this study, indicate that the Portuguese version of the instrument has good psychometric characteristics in this sample of nurses, allowing measuring the conflict experienced between work and family life. The assessment methodologies reflected the factorial structure of the original instrument, replicating in Portugal the two-dimensionality of the construct, work-to-family conflict and family-to-work conflict. The reliability of the scales was high, with Cronbach's Alpha Coefficients assuming values indicating a good internal consistency. Discriminant validity, as projected [3], indicated that WFC is strongly correlated to psychological distress, and with nurses stress responses (pressure-overload and guilt). These findings show that the Portuguese version of the instrument has the psychometric properties to be reliably used with hospital nurses.

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Measures for Managing Psychosocial Risks in Vocational Education and Training Organizations

Sari Tappura and Johanna Pulkkinen

Abstract In Finland, vocational education and training (VET) providers are responsible for organizing vocational education in their respective regions. VET providers' personnel consist of teachers, support services personnel and managers. Today, VET providers are facing major organizational changes due to educational reform and the tight economic situation. In these situations, VET providers' personnel may encounter decreased occupational health and safety (OHS) due to psychosocial risks. The problems arising from organizational changes are often interpreted as deficiencies in the competence of personnel or as stemming from occupational burden. At the same time, activities promoting the well-being of personnel often focus on individual physical activity. However, organizational resolutions are needed to improve OHS and the well-being of personnel in VET. The objective of this study is to generate measures for managing psychosocial risks in VET organizations. Six large VET providers with approximately 3700 full-time employees participated in the study. An interview study was carried out to investigate employees' conceptions of their OHS risk factors and the possibilities to reduce their overburden. A total of 58 people representing teachers, support service personnel and managers were interviewed. The interview results were qualitatively analysed and validated in workshops. Based on the analysis, a collection of organizational measures to improve OHS of personnel and to reduce their overburden were suggested. The measures provide a systematic and practical approach for managing psychosocial risks in VET and other educational organizations.

Keywords Vocational education and training · Occupational health and safety · Psychosocial risks

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1 Introduction

In Finland, vocational education and training (VET) providers are responsible for organizing vocational education in their respective regions. In 2018, there were 149 VET providers in Finland owned by municipal federations, municipalities, private companies and the state [1]. A single VET provider typically operates in numerous vocational institutions across a large area covering several municipalities [2].

In recent years, Finnish VET providers have encountered major changes due to vocational education reform, permanent diminishing of the financing, digitalization and changes in working life that have challenged their structures and procedures. The procedures are increasingly changing from VET-centred procedures to student-centred ones [3]. This situation requires new pedagogics, services and ways of action. The resources must be adjusted to the situation, and major organizational changes are needed to discover new ways of running the education system. Many VET providers have had occasion to decrease the amount of personnel to adapt their operation to the situation.

In the current challenging climate, VET providers' personnel experience mental overburden and related negative OHS effects [4]. These changes challenge the competence, development and readiness for change of employees, which may cause them stress. They may encounter decreasing OHS and work ability due to overburden. The problems arising from the organizational changes are often interpreted as deficiencies in competence or as stemming from occupational burden. At the same time, activities promoting the well-being of employees often focus on individual physical activity. Therefore, organizational resolutions and preventive measures are needed to promote work fluency and the well-being of VET personnel during times of austerity.

Developing OHS is one way to improve performance and well-being in VET provider organizations. Improving OHS can help increase the well-being and job satisfaction of employees; can help reduce occupational injuries, ill health, sick leave, resignation, early retirement and the related costs; and consequently can improve performance [5]. Developing OHS is a good way to demonstrate to employees that the top management (employer) cares about their well-being. Moreover, developing OHS may help in attaining the other objectives of VET providers, including improving the quality of education and the health, safety and well-being of students [6]. However, the OHS of students is not discussed in this paper as such, but it can be seen as a result of VET providers' positive OHS culture and the employees' OHS and well-being [6].

OHS regulations outline the essential OHS requirements for employers in Finland [7, 8]. Therefore, VET providers have a regulatory obligation to provide healthy and safe workplaces as far as is reasonably practicable. Establishing an OHS culture with effective OHS processes helps in meeting this duty of care [6, 9]. Hence, OHS issues are the responsibility of management in VET provider organizations. The management of OHS can be integrated into existing management processes rather than developing separate procedures [6, 10].

In today's working life, the mental and emotional demands of work have increased, and psychosocial risks have emerged in addition to the inherent physical, chemical and biological risks [11–13]. Psychosocial risks are related to the design and management of work and its organizational context, which have the potential to cause harm to employees [14]. They may result in negative psychological, physical and social outcomes such as work-related stress, burnout, depression or injuries [12]. Psychosocial risks arise from, for example, job insecurity, high workload and work pressure, violence, bullying, harassment and unresolved conflicts, and they are widely recognised as major challenges to OHS, weakening employees' safety, health and well-being and organisational performance [11, 15–17]. Moreover, the psychosocial risks are often perceived as difficult to manage, and more support is necessary for managers to effectively manage these risks [15, 18, 19].

In Finnish educational provider organisations, the occupational burden generally arises from role overload and constant interruptions, poor indoor air quality in school buildings, harassment and other kinds of inappropriate behaviour and the threat of violence [20], which are for the most part considered psychosocial risks [11]. Role overload has been found to be one of the major OHS strain factors for teachers [21].

Previous research on OHS in the educational sector often emphasizes individual coping strategies, including developing employee engagement, psychological capital, resilience and physical and stress management training [21–23]. According to previous studies, exercising, using relaxation techniques and seeking social and emotional support, positive appraisal and planful problem solving are positive coping strategies as well [21, 24]. Nevertheless, as the occupational burden is typically organization-based, emphasis on organization-based interventions and coping strategies are needed. Moreover, using a variety of measures is necessary [23].

The Finnish VET provider organizations have a large variety of OHS management practises in use, but their implementation varies a lot and the overall picture of OHS management is somewhat unclear [25]. The defined procedures and practices are not necessarily followed in reality [25]. Moreover, OHS issues, including psychosocial risks, are inadequately addressed in current school safety models [6, 26]. Therefore, more emphasis on practical measures to support managers in managing OHS is needed.

This study discusses the management of psychosocial risks in VET provider organizations during major changes in the educational sector. The objective is to generate practical measures for managing psychosocial risks in VET organizations. This study focuses on VET provider organizations as an example of educational organizations and on providing useful guidance for educational organizations in their efforts to promote OHS.

2 Materials and Methods

This study is part of a larger research project carried out between 2015 and 2017 [27] and employs a qualitative approach [28] due to its descriptive and contextual nature. Six large VET providers with approximately 3700 (2017) full-time employees participated in the study.

An interview study was carried out to investigate employees' conceptions of their OHS risk factors and the measures to reduce their overburden. A total of 58 people representing teachers, support service personnel and managers were interviewed between 2016 and 2017 (see Table 1). The number of interviewees in one VET provider varied between 8 and 11.

The interview results were qualitatively analysed and validated and complement though presentations and discussions in six workshops. The workshop participants were the OHS and human resources (HR) professionals of the participating organizations, such as safety managers, heads of OHS, OHS delegates, and HR managers.

The organizational measures for managing the psychosocial risks were revealed from the interviews, and existing good practices in other organizations. The measures were tested and further developed in the participating organizations to fit their purposes. Based on the feedback information, a collection of measures was suggested to help the VET organizations manage their psychosocial risks.

3 Results

Based on the interviews and workshops, VET organizations need organizational measures to manage their psychosocial risks. They had basic measures to manage regulatory OHS issues, such as workplace violence and inappropriate behaviour. More measures were developed with regard to the OHS risks perceived in VET organizations, and more emphasis on psychosocial risks was laid. Table 2 gives a summary of the measures. The detailed description and application of each measure are presented in the report of the larger research project [27].

Table 1 Background information about interviewees' occupations (n = 58)

Occupation	Number of interviewees
Principal or deputy principal	2
Sector manager	2
Development manager	1
Training manager	4
Team leader (teaching)	4
Teacher, lecturer, or trainer	26
Support services manager	8
Support services personnel	11

Table 2 Summary of the measures for managing psychosocial risks in VET organizations

Measure	Remarks
Organizing risk assessments	Emphasis on psychosocial risk factors of different personnel groups
Definition of OHS responsibilities and tasks	Responsibilities of the managers, OHS professionals and other personnel
Definition of teaching and guidance personnel's OHS responsibilities	Responsibilities for OHS of the students working under VET organization's control
Induction and working instruction	Emphasis on managers' OHS responsibilities and psychosocial risks
Personnel OHS competence and training	Emphasis on systematic OHS competence development of the personnel
Safety walks and audits	Engaging personnel in OHS work
Controlling threatening and violent situations	Emphasis on prevention and the training of personnel
Controlling the mental burden	Emphasis on mutual discussions on major stress factors and related control means in the work community
Developing membership of the work community and business-like behaviour	Emphasis on encouraging employees to be an active, positive and constructive members of the work community
Workplace conciliation	Emphasis on learning dialog and conflict resolution in the work community

Risk assessments in the work place should be systematic and exhaustive, covering all risk factors. However, due to the nature of work in VET organizations, more emphasis on the psychosocial risk factors of different personnel groups is needed. There are several checklists of psychosocial risk factors to be utilized in the assessment.

Personnel OHS responsibilities and tasks should be defined to make them visible and to better manage OHS in VET organizations. The OHS responsibilities of teaching and guiding personnel should be clarified, as they are responsible for the students working under their control during their education.

The VET organization is responsible for induction and working instruction with regard to its working conditions and environment and related safe working procedures. During the induction process, more emphasis on managers' OHS responsibilities and psychosocial risks is needed in VET organizations.

The OHS competence development and training of personnel should be systematic to ensure sufficient knowledge on OHS procedures, the ability to act in dangerous situations and information about the available support. Safety walks and audits are good ways to engage personnel in the OHS work by practicing observing the work environment and conditions. Procedures and training related to controlling threatening and violent situations is important to prepare personnel to act appropriately in threatening situations. It may also help personnel to prevent the threatening situation from escalating into violence.

The mental burden can be controlled and decreased by mutual discussions on the major stress factors and organizing the work in the work community. Related control means can be tested and divided in the work community. Because inappropriate behaviour often causes mental burden in the work community, it is important to develop the sense of membership in the work community and business-like behaviour among employees. Employees should be encouraged to be active, positive and constructive members of the work community. When inappropriate behaviour escalates into conflicts, workplace conciliation can be used to learn dialogue and conflict resolution in the work community.

With regard to all the organizational measures, a focus on prevention is important. The development of measures and training provides personnel with the ability to act in and cope with burdening situations. Moreover, the existing measures heighten the feeling of safety, which may decrease the mental burden of the personnel.

4 Discussion

Psychosocial risks are widely recognized as major challenges to OHS, as they weaken occupational health and well-being and organizational performance [15–18]. According to studies by the European Agency for Health and Safety at Work [15] and Tappura et al. [19], more support is necessary for managers to effectively manage psychosocial risks. The current study aimed to emphasize psychosocial risks as a part of OHS management of VET providers in Finland. Moreover, the study aimed to generate practical measures for managers to effectively manage psychosocial risks in VET provider organizations.

Based on previous studies [4, 20, 21] and this study, psychosocial risks are the major OHS risks in educational organizations. In related articles, Tappura et al. [6, 25, 26] presented a general model and practices for managing the OHS of VET organizations. The current study adds to the previous studies by presenting practical measures for managing psychosocial risks, as the mental overburden is a major OHS risk factor among studied VET personnel [4].

Based on the interviews, workshops and literature, a collection of organizational measures to improve the OHS of personnel and reduce mental overburden was suggested. The collection of the measures was developed primarily for the needs of the participating VET organizations, and it took into account their existing measures. Therefore, the measures reflect the current situation and development needs of participating Finnish VET organizations, but they can be utilized in other educational organizations as well.

The measures provide a systematic and practical approach for managing psychosocial risks in VET and other educational organizations. The results may be utilized to support the work ability and well-being of personnel when reorganizing work due to major organizational changes in educational organization. The collection of measures can be adapted to the specific situations in VET organizations and can be utilized, for example, in induction and internal training. Developing measures to manage psychosocial risks helps VET organizations to improve employees' OHS and well-being and thus enables them to focus on performance during organizational change.

This study has some limitations as follows. It was descriptive in nature and it exploited a limited number of organizations. The study focused on organizational measures for managing psychosocial risks, and little was said about individual measures. In addition to organizational measures, for example, exercising, using relaxation techniques and seeking social support are practical individual coping strategies [21, 24]. Moreover, the practical utility of measures was not evaluated by their users in this study. In the future, the collection of measures should be implemented in practice and its usefulness should therefore be evaluated in by its users, namely managers.

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Part VI
Other Occupational and Emergency Issues

Effectiveness of Occupational Safety and Health Training Methods: A Study with Metalworking Small Enterprises

Beatriz L. Barros, Artemisa R. Dores and Matilde A. Rodrigues

Abstract The incorporation of proper training in Occupational Safety and Health (OSH) is of paramount importance for small enterprises. However, the method applied will influence its effectiveness. This study aims to explore and compare the effects of two training methods on safety behaviours and OSH knowledge, when applied in metalworking small enterprises. For this study were selected an active method, with group discussion, and an expository method, with formal exposure. A total of 212 workers participated in this study. The sample was divided into three different groups: two intervention groups (active and passive group) and one group without intervention (control group). A questionnaire was developed to assess the following dimensions: safety behaviour (safety compliance and safety participation) and OSH knowledge. It was administered before, and one month after, the training sessions. The results indicate that OSH training had a positive, but limited, effect on the variables under study. Significant differences were found, between the two assessment moments for OSH knowledge with both the expository and the active methods. Significant differences between the three groups were found after the intervention for OSH knowledge. However, no significant differences were observed in any case for safety behaviours.

Keywords Employees · Occupational safety and health · Small firms · Training

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1 Introduction

Current statistics show that the number of work accidents still remains high, in particular in small-sized enterprises [1]. In order to reduce the number of occupational accidents, Occupational Safety and Health (OSH) prevention activities become of high relevance. In this field, OSH training is considered an essential tool to improve OSH performance, contributing to the reduction of accident rates [2–4].

Previous studies suggest that unsafe behaviours are one of the most important factors concerning the occurrence of occupational accidents [5, 6]. In this way, and in order to reduce injuries in the workplace, it becomes important to focus attention on the behaviours that workers adopt during their daily work. Several studies have shown the effectiveness of training in improving risk awareness and safe behaviours, representing safety improvements in the workplace [3, 4]. The lack of knowledge about this topic has also been pointed out as an important factor in the study of accidents [7]. OSH training plays an important role in acquiring knowledge and skills for the workers perform the same tasks/work in a safer way [8].

OSH training is of particular relevance to small-sized firms, given the limited financial, human and technological resources, which in turn can constrain the safety performance in these enterprises [9]. In fact, small businesses show lower aptitude to respond to this type of issues. However, despite the relevance of the training on OSH to these organizations, in order to achieve effective results, it is necessary to adopt methodologies appropriate to the reality of the enterprise where the training is delivered.

In what regards to training methods, previous studies suggest that more engaging methods, such as the ones involving the active participation of the trainees, especially those applied in the real field, are the more effective in promoting safer behaviours [10–12]. It was also verified that traditional training methods (expositive) have more positive results when they are coupled with techniques that require the involvement and the active participation of the workers [10, 13]. This is in line with what has been pointed out in other studies, which indicate that the training that requires the active participation of the trainees is more effective than the traditional expository training [3, 14].

The Health Belief Model (HBM) is a model that focuses on the cognitive factors that are considered causal mediators of behaviours [15, 16]. This model has been used to predict behaviours mainly in the health area, in non-occupational contexts. However, when adapted to the OSH field, this model postulates that a worker who feels susceptible to a certain risk, considers the situation as a serious problem, and takes in consideration the benefits of adopting the target behaviour instead of the associated barriers, becoming more predisposed to adopt safe behaviours. Despite that, there are not enough evidences regarding the effect of a training method supported in this model, mainly when applied to small-sized firms. This study aims to explore and compare the effects of two OSH training methods on safety behaviour (an active method, with group discussion, and an expository method, with formal exposure) and analyse the effect of OSH knowledge when applied in metalworking small enterprises.

2 Methodology

2.1 Sample

A total of twelve small-sized enterprises from the metalworking industry participated in this study: 6 companies constituted the intervention group and 6 companies the group without intervention. The enterprises were randomly assigned to each group. Data collection involved 212 participants, distributed by three groups: an experimental group—EG (with the active method—discussion group), an active control group—ACG (with the expository method—formal exposure) and a passive control group—PCG (without intervention). Most of the participants were males (92.5%) with mean age of 40 years old (M = 40.2 year; SD = 12.1 year).

2.2 OSH Pedagogical Program and Training Methods

The workers' training needs were identified through two different approaches: (1) by conducting a focus group with 6 OSH practitioners that operated in the sector, and (2) by auditing the companies in order to characterize the general workplaces and environment conditions, machines' safety and safety behaviours. Training materials from different sources, such as the ones delivered by the Workplace Safety and Health (WSH) Council [17] were also used to support the definition of the pedagogical programme. It was organized in three parts. The first part consisted on an introduction to the occupational accidents and to the diseases in the metalworking industry. It were also addressed legal frameworks, including employers' and workers' duties and responsibilities. The second part addressed risk factors in the metalworking industry: physical, mechanical and ergonomic risk factors, chemical exposure, and fire hazards. At the end, risk control measures were presented.

During the training sessions two different methods were applied: (1) an active method, supported on the HBM (based on group discussions), and (2) an expository method with formal exposure. A power-point presentation was designed to support the training sessions where the expository method was used. This presentation was used as a reference to the design of the sessions in which the active method was applied, ensuring that the same contents were taught in the different types of sessions. Active training sessions were based on discussions, which were triggered with images, videos and studies. The presentation in power-point was prior tested with a sample of 10 workers in order to verify contents and its suitability to the reality of the metalworking sector, as well as to the time of the session.

2.3 Training Effectiveness Assessment

A questionnaire was developed to assess the effects of the training sessions on safety behaviour and OSH knowledge, in response to different training methods. In the first part of the questionnaire, the following sociodemographic and professional variables were surveyed: age, gender, educational level, seniority in the metal-working sector and in the company, department, function, seniority in the current function, work shift, employment contract and occupational accidents and diseases. In the second part of the questionnaire, a Likert scale with 8 items were included to analyse the self-reported safety behaviours (1 = totally disagree, 5 = totally agree). The scale was adapted from Griffin and Neal [18]. It assesses two dimensions of safety behaviours, i.e., safety compliance and safety participation. Safety compliance can be defined as the extent to which workers comply with safety procedures and work safely, and was assessed through 4 items. The Cronbach's Alpha was 0.82 (example of an item: "I keep my workplace clean and organized"). Safety participation is related to the employee's involvement with safety issues, and was evaluated by 4 items. The Cronbach's Alpha was 0.69 (example of an item: "I report incidents that occur to me or my co-workers").

The questionnaire also included sixteen items to assess OSH knowledge. Items were elaborated based on the information collected from both focus groups and literature review (see., e.g., Glendon and Litherland [19] and Mostafa and Momen [20]). Workers were requested to choose one option out of three possibilities: "True", "False" and "I don't know".

The validity and reliability of the questionnaire were analysed in a pilot company with 30 employees. The questionnaire was applied before and one month after the training sessions. In the control group, the questionnaire was applied in the same periods.

2.4 Data Analysis

Descriptive statistics were computed to describe variables in the same way as previous studies [12, 16]. For the OSH knowledge, the results were presented as the percentage of correct answers. Normality was tested through the application of the Kolmogorov Smirnov test and the analysis of standardized residual distributions, skewness, and kurtosis. Parametric tests were applied, namely *t*-test for paired samples (used to compare the rankings of each item before and after the training), *t*-test for independent samples (to compare differences between the two interventions) and *ANOVA* test (to compare differences between the three types of interventions). A significance level of $\alpha = 0.05$ was considered in the present study. Data analysis procedures were performed using the statistical software package Statistical Package for Social Sciences (IBM SPSS® version 22).

3 Results and Discussion

The effects of a pedagogical intervention on Safety behaviours and OSH knowledge through the application of two different training methods were analysed, being the results presented in Table 1. This analysis was considered relevant because there are no studies analysing the viability of different methods at OSH level, namely in small-sized firms.

Concerning safety behaviours, for both dimensions (safety compliance and safety participation), the results between the pre- and post-training moments were similar and there were no significant improvements after the intervention. These results were not expected, since previous literature have showed significant improvements in safety behaviours (or intended safety behaviours) after OSH training (see e.g., Burke and Sarpy [2]). The fact that this study had only a single training session can help to explain these results. To promote safe behaviours, workers' risk acceptance and perceptions should also be changed, being important a continue intervention [12]. However, other research works denote that not always workers who had experienced more training hours present higher safety behaviours [21]. This suggest that not only the number of training hours can be important when we are trying to improve safety behaviours, but also the training method applied.

For safety knowledge significant differences between both moments (pre- and post-training moments) were found for both intervention groups ($p < 0.001$). According to Table 2, there was an increase in the percentage of correct responses from pre- to post-intervention assessments. Of the 16 questions, the question 10

Table 1 Comparison of the mean scores of the dimensions of safety behaviour before and after the training intervention

Variable	Group	Before training x (sd)	After training x (sd)	*p*-value
Safety compliance	ACG	15.26 (2.19)	15.17 (2.25)	0.654
	EG	15.15 (2.54)	15.47 (2.07)	0.212
	p-value	0.814	0.468	
	PCG	15.43 (2.46)	15.50 (2.41)	0.127
	p-value	0.777	0.673	
Safety participation	ACG	14.76 (2.26)	15.00 (2.40)	0.264
	EG	14.57 (2.41)	14.34 (2.03)	0.357
	p-value	0.668	0.128	
	PCG	14.32 (2.57)	14.44 (2.55)	0.181
	p-value	0.554	0.282	
Occupational safety and health knowledge	ACG	69.33 (16.53)	87.27 (15.36)	0.000
	EG	68.04 (15.10)	88.80 (13.83)	0.000
	p-value	0.675	0.590	
	PCG	68.45 (14.92)	68.63 (14.91)	0.083
	p-value	0.905	0.000	

Table 2 Level of knowledge in percentage of correct answers, by type of training

Occupational safety and health knowledge	ACG				EG			
	Q1 (%)	Q2 (%)	Q2 − Q1	*p*-value	Q1 (%)	Q2 (%)	Q2 − Q1	*p*-value
1. Chemicals can enter the body through the skin	88.9	98.1	9.2	0.058	92.5	98.1	5.6	0.182
2. It is only above 87 dB(A) that I am exposed to dangerous noise levels	42.6	81.5	38.9	0.000	39.6	75.5	35.9	0.000
3. Deafness is a reversible occupational disease	57.4	81.5	24.1	0.000	43.4	81.1	37.7	0.000
4. If a worker uses vision correction glasses, they no longer need to wear protective eyewear	81.5	94.4	12.9	0.033	71.7	100.0	28.3	0.000
5. It is possible to remove the protections of the machines, as long as it is to increase production	85.2	92.6	7.4	0.159	84.9	90.6	5.7	0.261
6. It is not necessary to use the hearing protectors during all the day of work, since the important thing is to use it most of the time	72.2	83.3	11.1	0.135	69.8	90.6	20.8	0.004
7. The worker is responsible for purchasing his personal protective equipment	53.7	75.9	22.2	0.002	52.8	86.8	34	0.000
8. If an accident at work occurs at the premises of the company, the responsibility for its repair is always from the employer	48.1	68.5	20.4	0.010	62.3	71.7	9.4	0.200
9. Safety at work is of the sole responsibility of the employer	79.6	92.6	13	0.033	84.9	88.7	3.8	0.485

(continued)

Table 2 (continued)

Occupational safety and health knowledge	ACG				EG			
	Q1 (%)	Q2 (%)	Q2 − Q1	*p*-value	Q1 (%)	Q2 (%)	Q2 − Q1	*p*-value
10. The repair of an occupational disease is carried out by the insurance company	16.7	83.3	66.6	0.000	17.0	81.1	64.1	0.000
11. Whenever there is a risk of projection of filings the worker must wear protective goggles	92.6	94.4	1.8	0.659	94.3	100.0	5.7	0.083
12. I must wear steel toe boots because they prevent smashing of the fingers due to falling objects	96.3	98.1	1.8	0.569	98.1	100.0	1.9	0.322
13. To extinguish a fire in an electric panel an extinguisher of category ABC is the adequate one	20.4	64.8	44.4	0.000	9.4	64.2	54.8	0.000
14. Removing machine protections helps increase productivity and reduce workplace accidents	94.4	94.4	0	1	86.8	100.0	13.2	0.007
15. Employees who use respirators should wear goggles, protective gloves and hearing protection	94.4	98.1	3.7	0.322	96.2	100.0	3.8	0.159
16. To reach the higher shelves the worker can use the truck to be lifted	85.2	94.4	9.2	0.058	84.9	92.5	7.6	0.044

("The repair of an occupational disease is carried out by the insurance company") and 8 ("If an accident at work occurs at the premises of the company, the responsibility for its repair is always from the employer") obtained significant improvements in the experimental group and in active control group, respectively.

No significant differences were found between the three groups, both before and after the intervention (Table 1), except in what regards to OSH Knowledge after intervention ($p < 0.001$). In fact, significant differences were found when compared both intervention groups and the control group after the intervention, emphasizing the effect of training on workers' OSH knowledge. However, no significant differences were found between the two intervention groups regarding this variable.

In general, the results of this study showed a limited effect of the training intervention on the variables under analysis. The improvements after the training intervention were smaller than the excepted, even for OSH knowledge. Additionally, it was expected to achieve significant improvements in the active method with discussion group, since a more engaging method was applied. Burke et al. [14] demonstrated that training methods that require greater involvement by workers are more effective in terms of safety performance and knowledge acquisition. However, the improvement found in this study was not significant when the two training methods were compared. Robson et al. [4] argue that the evidence in favour of the engagement hypothesis is weak and that more evidence should be found. Adams et al. [22], in a study that aimed to evaluate the effectiveness of two education methods (traditional vs. new education paradigm), found that although there was a significant overall decrease in rates of injuries, the difference between the two intervention groups was not significant. Brahm and Singer [23] have stated that there is no training method better than others and that its effectiveness depends on the needs and characteristics of each company. In our study, the number of training sessions could be a limitation. In future research additional training sessions will be provided to the workers, including training in the workplaces.

4 Conclusion

This study assessed the effect of training on safety behaviours and OSH knowledge, comparing two different training methods. The results obtained showed, in general, a limited but positive effect of the training on safety behaviour and occupational safety and health knowledge. Despite that, no significant differences were found between the two training methods, suggesting the need of additional studies.

The results presented in this paper are part of a larger study where the effects of the training methods on other dimensions were analysed; only a part of the results were presented here. In fact, and despite the importance of the results obtained and presented, there is a need of more research focused on attaining a better understanding of how OSH training can be more effective in small-sized firms.

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A Brief Overview of the Use of Collaborative Robots in Industry 4.0: Human Role and Safety

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Abstract Industry 4.0 is a new industrial paradigm that brings new challenges for workers as they have to actively collaborate with robots in an interconnected environment. The main purpose of this paper is to give a brief overview of how collaborative robots can be used to support human workers in Industry 4.0 manufacturing environments. The use of collaborative robots certainly brings many advantages as these machines enable more efficient product systems by supporting workers with both physical and cognitive tasks, as is the case of exoskeletons. On the other hand, human–robot interaction might also have some risks if human factors considerations are not well thought through throughout the process. Moreover, it becomes clear that the role that humans have been playing so far in a manufacturing environment is rapidly changing. Human workers will have to adapt to these new systems by acquiring and improving a set of skills that have sometime been neglected until nowadays.

Keywords Cobots · Human–robot interaction · Collaboration

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1 Introduction

Globalisation and the increasing demand for unique products has led to new industrial challenges. To ensure competitiveness, industries are now forced to move past the mass production paradigm and start to focus on more advanced manufacturing techniques with the human as the core of a production system (both as a worker and as a customer) [1]. The Industry 4.0 concept came to revolutionise the industrial environment and to help companies cater to the new global market's needs [2].

The industry 4.0 concept, also known as the fourth industrial revolution or digital revolution, aims at surpassing the traditional manufacturing systems by fully integrating physical and the virtual worlds [3]. In these systems everything is connected, from machines, tools and workers to products and customers. To achieve this, there are many technologies associated that need to be set in place; a few examples include internet of things, big data, cloud computing, augmented reality, robotics, collaborative robots, and additive manufacturing.

The majority of the studies that have been conducted in the field of Industry 4.0 are related to the use and implementation of these new technologies in industrial systems. However, and despite the fact that the human is considered as an important part of the system, not many studies seem to take in consideration human factors and ergonomics [4]. The lack of consideration for human factors might result in unsuccessful implementations of this new paradigm as people will tend to feel frustrated, neglected and overpowered by robots [4]. In an environment filled with interconnected intelligent machines where the human still plays an important role, it is important to have a great understand of how they can interact so that the workflow runs as smoothly as possible [5]. These types of complex human–robot systems need to be informed by human factors and ergonomics to preserve the safety of both machines and humans [6].

The purpose of this paper is to give a brief overview of how collaborative robots might be used to assist humans in manufacturing environments that implement Industry 4.0. Furthermore, a succinct outline of safety-related issues (such as hazards from human–robot collaboration and the implementation of safety systems to avoid incidents) that might arise from human–robot collaboration is discussed, as well as the future role of humans in this new manufacturing era.

2 Using Collaborative Robots to Support Human Work in Industry 4.0

The use of collaborative robots, or cobots, is one of the great advantages of implementing an Industry 4.0 system. These robots can be used for a myriad of different activities. The most obvious one is the replacement of physical work. Cobots can be used in manufacturing as assistants to support workers with tasks where a great physical effort is required, as for example the handling of heavy loads [7]. The use of these robots is very useful to predict and minimize work-related musculoskeletal disorders derived from repetitive and forceful tasks [5]. These robots can, not only, be used to assist on minimizing efforts to the workers, but also to establish prohibited zones or facilitate the appropriate trajectories to perform the task efficiently [7].

2.1 Support of Physical Work

The most common use for robots in the industry has been to assist with physical work [1]. Among many other applications, a great example of support for physical work in advanced manufacturing environments is the use of exoskeletons to reinforce the workers' physical abilities (e.g. strength or fine-motor skills) while lowering the physical strain [1, 8, 9]. Exoskeletons can be used in either the upper or lower body (or both) and are classified as passive when they provide support, rigidity and protection or as active when they provide increased strength and sensitivity [10]. One active upper body exoskeleton has already been tested in the automotive industry to assist with repetitively overhead operations [10]. This exoskeleton was used to provide support to the workers' arms so that they could lift them with easiness, thus reducing the load imposed on the joints and muscles, improving the health and safety at work and the overall quality of work. One passive lower body exoskeleton has also already been tested in the automotive industry to assist continuous standing work [10]. This exoskeleton was couple to the workers' lower limbs and acted as a chair when the workers' felt they needed to change positions and rest, thus reducing the load imposed on the legs, facilitating the adoption of correct postures, while keeping flexibility and mobility.

Apart from exoskeletons, and according to Kleindienst et al. [1], other examples of support that robots can provide for physical work include:

- Automate monotonous tasks;
- Adapt tools and workstations according to the workers' anthropometrics and movements restrictions and limitations;
- Adapt interfaces (signals and warning signs) taking in consideration the workers' hearing or visual restrictions and limitations;
- Monitor body data to diminish health and safety related hazards;
- Improve human-machine-interaction by recognizing the human action-intension with technologies like embedded brain reading.

2.2 Support of Cognitive Work

The Industry 4.0 paradigm implies that industrial work becomes more knowledge-intensive, and consequently, the support for cognitive work becomes relevant in the manufacturing industry as well. Likewise, there are a number of tasks that robots and computers can do better and faster than humans at a cognitive level (e.g. looking for a specific, pre-defined pattern in a large database). Kleindienst et al. [1] give a few examples of tasks that robots and computers would be able to support workers with in terms of cognitive work:

- Visualise alternative decisions to reduce biases in decision-making;
- Store large amounts of information thus reducing the need for short-term memory effort—the information is only presented when relevant and necessary;
- Suggest work breaks to improve performance and concentration—suggestions could be based on age and on the monitoring of physiological signals;
- Observe work processes and suggest improvements to reduce errors and support continuous professional learning.

3 Safety in Human–Robot Collaborations in Industry 4.0

Increasing the connectivity and collaboration between humans and machines in a manufacturing system impacts the overall safety. In these environments, safety is mostly focused on protecting humans from the surrounding systems and is considered a priority in any industrial plant [11].

Until now, for increase safety, systems have separated the robot and human workspaces. However, to enable an efficient and effective collaboration between humans and robots, these barriers need to be eliminated [12]. In their place, new types of safety systems need to be introduced—systems that are enabled with avoidance strategies and are capable of preventing or minimizing the risks of collisions by detecting obstacles as well as their motion. Moreover, to avoid unforeseen dangers in the manufacturing setting, the planning of tasks should be done in a more cautious and meticulous way with the inclusion of the limitations of each participant (either it is human or machine) [13].

3.1 Hazards from Human–Robot Interaction and Collaboration

Having humans and machines working together efficiently is a complex process that might have some risks for both humans and robots. Khalid et al. [11] identified a number of hazards that might arise from this human–robot interaction. These

Table 1 List of types of hazards from human-robot interaction

Type of hazard	Examples of hazards
Hazards from robot during collaboration	• Robot characteristics (e.g. speed, force, torque, acceleration, momentum, power) • Tight safety distance limit in the collaborative workspace • Trajectory taken by the robot • Physical obstacles against robot operation during collaboration • Fast worker approach speed and robot's slow reaction time • Mental stress to worker due to robot characteristics
Hazards from the industrial process during collaboration	• Duration of collaboration processes • Material flow and routing during processes • Transition time from collaborative operation to other operation • Ergonomic design flaws for operation and maintenance • Task complexity in collaborative workspace • Mental stress to worker due to collaborative industrial process
Hazards from robot control system mal-function during collaboration	• Physical obstacles in front of active sensors used in the collaborative workspace • Obstacles against unobstructed means of exiting the collaborative workspace at any instant • Visual obstruction for robot in collaborative work-space due to vantage point of operator • Control layer malfunction and misuse of collaborative system by attacker under a cyber-attack in a connected environment • Workers' misuse of the system • Wrong perception of industrial process completion by the robot

Adapted from [11]

hazards might come from either (i) robots during human–robot collaboration, (ii) the industrial process during human–robot collaboration, or (iii) robot control system malfunctions during human–robot collaboration. The list can be found in Table 1.

3.2 *Safety Systems to Protect Humans in Industry 4.0*

Developing systems that intend to enable a safe collaboration between humans and robots should entail knowing and quantifying the limits of humans in regards to the level of pain tolerance and the level of injury. This is very relevant as this information as it will allow the creation of systems that minimise the severity of possible

Table 2 Safety systems in industrial robot collaborative environments

Purpose of system	Hardware	Devices
Quantify level of injury by collision	Estimation of pain tolerance	Human arm emulation system
	Evaluation of injury level	Standard automobile crash-test
Minimize injury by collision	Combination of several mechanical compliance systems	Viscoelastic coverings Absorption elastic systems
	Light weight structures	Carbon fibre, aluminium
	Sensorised skin	Tactile sensors
	Prioceptive sensors	Encoders
	Combination of sensors and RGB-D devices	Force sensors, RGB-D devices
Collision avoidance	Motion capture systems	Sphere geometric models/SSLs
	Sensors capturing local information	Capacitive, ultrasonic, laser scanner sensors, infrared, led
	Artificial vision systems	One or several standard cameras, Fisheye
	Range systems	ToF laser sensor One or several range cameras
	Combination of vision and range systems	Standard CCD and range cameras
	RGB-D devices	One or several RGB-D devices

Adapted from [12]

collisions. However, and since collisions cannot always be avoided, different mechanical systems and safety strategies for collision detection should be implemented in order to minimize injury in case of human–robot collision [12]. Furthermore, more than mitigating the consequences of human–robot collisions, next generation industrial systems should be able to prevent unintentional contact [12]. Accordingly, Robla-Gomez et al. [12] provide a structured framework for safety systems in robotic environments, where they divide the systems by purpose and then indicate the respective hardware systems to be employed and the devices to be used—Table 2. According to these authors, Industry 4.0 should adopt three types of safety systems that are able to (i) quantify the level of injury by collision, (ii) minimize the injury in human–robot collaborations, and (iii) avoid collisions.

4 The Future of Human–Robot Collaboration in Industry 4.0

The implementation of the new Industry 4.0 paradigm denotes mandatory substantial changes to the production processes. The new production systems will become increasingly complex at several levels, namely on [13, 14]:

- work content: variety, cycle, skills, uncertainties, exposure;
- work organization: team scheduling, overtime, rush orders;
- management: responsibilities, communication, roles, relations, problem solving;
- other organizational factors: promotion and pay raises, job security, social value of the work.

4.1 The Future Role of Human Workers in Industry 4.0

These new manufacturing systems that will be self-learning and self-decision making able, might limit the future industrial roles for humans [11]. However, it does not mean that humans will be completely replaced by robots in all parts of a manufacturing systems. This new industrial transformation will allow industrial robots to go beyond the tasks they have been doing until now—they will not be restricted to the transfer of objects, or do repetitive tasks, they will be able to combine their skills with human skills in a collaborative manner [12]. Instead of a competition to see who is being replaced, the integration of cobots in the industrial environment should be seen as a profitable partnership as Industry 4.0 workers will share most of their time collaborating with machine in complex tasks [1].

Human creativity and rapid adaptably and flexibility skills should not be replaced by robots, as the latter are better at other tasks, like searching for a given pattern in large database, than humans [1]. As such, humans will assume more leadership and supervisory type of roles on the shop floor, as they still have a greater ability to reason and make decisions that cannot yet be replaced by autonomous systems [1, 15]. The role of human workers will mostly focus on compensating for the technological limitations and act as a decision maker for an improved production planning and control with the support of advanced systems [16, 17]. The management of large amount of information and data, alongside interacting with complex machines and systems, will be the basic elements of future work tasks [8]. Examples of tasks might include the observation and regulation of highly automated complex processes and the supervision and efficient application of machines.

4.2 Skills of Workers in Industry 4.0

The Industry 4.0 environment will need different skills and competencies of the workers on the shop floor as the operations and tasks of a given productive process will be significantly different than what they have been so far [1]. These environments will encompass very complex, interconnected, and automated systems that will demand for a different level of personal qualifications [1]. This new paradigm will force a new type of relationship between humans and machines, enhancing cooperation and collaboration. Accordingly, it is essential to identify and plan the

Table 3 Future technical skills and qualifications of Industry 4.0 workers

Type of skill	Skill
Must	IT knowledge and abilities Data and information processing and analytics Statistical knowledge Organizational and processual understanding Ability to interact with modern interfaces
Should	Knowledge management Interdisciplinary knowledge about technologies and organisations Awareness for IT security and data protection Specialised knowledge of manufacturing activities and processes
Could	Computer programming and coding abilities Specialised knowledge about technologies Awareness for ergonomics Understanding of legal affairs

Adapted from [1]

most important professional and transversal skills that will enable workers to cope with the advanced manufacturing technologies [2]. System competences, that include recognizing elements in the production system, understanding functions and relationships within the system and predicting the system's behaviour will become basic qualifications for industrial workers in Industry 4.0 [1].

To thrive in the Industry 4.0 era, workers will be required to acquire a wide range of specific skills and will need to combine conventional task-associated expertise with computer skills [13, 18]. People should cultivate skills in the areas of design, use and supervision of intelligent machines that will be capable of assisting humans in the performance of tasks [2]. Kleindienst et al. [1] suggested a set of skills and qualifications that workers of companies implementing Industry 4.0 should have. Table 3 presents the technical skills and qualifications suggested by these authors categorised by the level of importance (must have, should have and could have skills).

Overall, it is noticeable that this new paradigm will require a shift from more manual labour to a more knowledge-based work, as a significant part of the future workers' tasks will entail activities that involve applying, searching, creating and sharing complex knowledge [19]. However, this might be a difficult adaptation, especially for an aging labour force that might not have the appropriate training and required skills [18]. Hence, it is important that workers are motivated, flexible and open to change so that they can collaborate more effectively [20].

5 Conclusion

The new demands of this contemporary global market have forced companies to shift to a new way of manufacturing their products. The fourth industrial revolution has come to give more flexibility to industrial systems so that they are able to cope with the increased mass customisation demand. Industry 4.0 puts the human at the centre of the system, making collaboration between humans and machines the focal point of concern. Efficient interaction in such complex system is hard to achieve and should be considered right from the design phase. This is an especially important issue as safety might be compromised when ill-fitted systems and collaborations are implemented. As such, it is important to understand that humans will have to adapt to this new environment by acquiring and improving some important skills, such as management and IT skills.

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From Conceptual Map to the Construction of a Character to Disseminate Inclusion of Visually Impaired People into University Libraries

Erilze Brito, Mônica Uchôa Cavalcanti and Laura Bezerra Martins

Abstract Accessibility for the visually impaired in the academic environment is a condition to facilitate the development of these individuals in these institutions. This work presents the creation of a character to disseminate knowledge about accessibility for inclusion of people with visual impairment in the Sectoral Library of the Education Center of the Federal University of Pernambuco (BIBCE-UFPE-Brazil), for that an investigation was carried out, having as target audience the administrative technicians of the service department of the library. The method used was a case study, with a qualitative approach, contemplating techniques of questionnaire and focus group. Our results indicated the inability of that technicians to treat visually impaired people due to lack of accessibility knowledge. From that results, it created a playful character to disseminate the conceptual and ergonomic accessibility elements in the Library.

Keywords Visual impairment · Accessibility · Cognitive ergonomics · Inclusive library

1 Introduction

Currently much is discussed about accessibility for people with disabilities (PcD) visual in University Libraries. Practice accessibility in these places, makes people with disabilities act in an inclusive and interactive form, this is about

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equalization of opportunities. The World Health Organization-WHO [1] points out that 40–45 million people in the world are blind, and another 135 million suffer from severe vision limitations.

This work investigates the inclusion of the visually impaired person in the University Libraries space, aiming to identify and analyze the factors that interfere in the access of blind and low vision persons in the Library of the Education Center of the Federal University of Pernambuco—BIBCE/UFPE-Brazil.

Addressing the issues of accessibility means insinuating itself into a two-way context: people's specific needs and the creation of structures to meet those needs.

The demand for visually impaired people in libraries has increased considerably, as a result of the support of the federal government, by launching the Law of Quotas, 13.409, in December 28, 2016 [2]. This law provides for the reservation of places for people with disabilities in the technical high school and college courses of the federal educational institutions. The demand for alternative information materials for people with visual impairment is still greater than the supply [3].

Nowadays there are many discussions about accessibility, but without seeking an understanding that enables a practical process and a real acquisition of new capacities of consciousness, and attitudinal changes.

The ergonomics for acting on issues of accessibility, universal design, organizational systems and adaptation of physical infrastructure through Brazilian and international standardization, allows the adaptation of spaces adjusted to the capacities and limitations of visually impaired people.

Accessibility refers to a range of variables related to the possibilities of access of a place and the activities that take place in the socio-physical environment [4].

Brazilian legislation incorporates principles of accessibility that encompass different dimensions. It defines accessibility as the condition for the security and full or assisted autonomy, of spaces, furniture and urban equipment, buildings, transport services and devices, systems and means of communication and information for persons with disabilities or with disabilities or reduced mobility [5].

The Brazilian Association of Technical Standards-ABNT, in NBR 9050 [6], defines universal design as "one that aims to meet the widest range of possible variations in anthropometric and sensory characteristics of the population".

The implementation of built environments that consider the various individual needs may not be enough, but is an essential condition for building an inclusive society [7].

2 Materials and Methods

The research project was developed between 2016 and 2018, submitted and approved by the UFPE Human Research Ethics Committee in order to obtain an opinion in compliance with Resolution CNS/MS No. 466/12, with the inclusion of descriptive data and project summarized in the Brazil Platform, with approval on November 1, 2017.

The research planning involved strategies for case study and qualitative approach, contemplating data collection techniques, the questionnaire and the focus group and non-participant observation, when the author of the work observes the displacement of the user in the Library.

The questionnaire was the technique used to investigate the degree of knowledge [8] about accessibility for Visual PcD, with a group of fourteen (14) BIBCE administrative technicians, and four (4) visually impaired users.

As an interactive tool, based on the results of the applied questionnaires, a training was developed for all employees [9], including the library coordinator and a blind user.

Basic knowledge about accessibility was studied, using a “conceptual map” (see Fig. 1), which graphically clarifies what is accessibility for inclusion, and can thus involve employees as an active part of the process of inclusion of people with visual impairment in BIBCE. The conceptual maps are hierarchically presented graphs to organize and represent a field of knowledge as tool of analysis of scientific works in steps of the bibliographical survey [10].

In order to explain the concepts of accessibility in ergonomics standards and through Brazilian standard 9050/2015, the IGGU character was created from the conceptual map, with the objective of providing information that generates knowledge through situations experienced in the everyday life of all. This character became a reference for the dissemination of knowledge about accessibility.

Regarding the ergonomic aspects, three different classifications were suggested, following some criteria, seeking to make comfortable and productive adjustments for employees and users, in order to adapt physical, cognitive, and organizational conditions to the characteristics of their users [11].

3 Results

The analysis of the library staff answers to the questionnaire questions showed that most of these professionals consider themselves unprepared to serve visually impaired people. For example, this was observed in the following question:

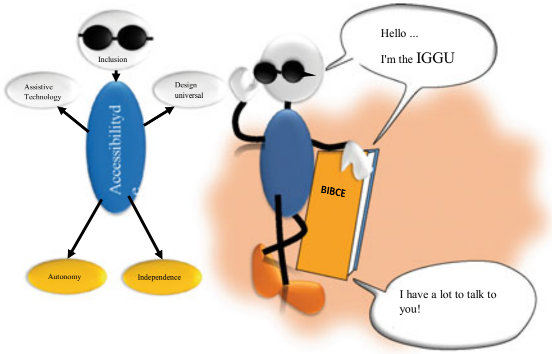

Fig. 1 IGGU character created from the conceptual map

P1 = Do you consider your knowledge about accessibility sufficient to meet a blind or low vision user? To this question, 83.3% of the servers stated that "no" know how to serve the visually impaired user, while 16.7% answered that "very little".

On technologies, it was asked: P2 = Can you identify, explain and use assistive technology, equipment created and designed to make life easier for the disabled person? The result showed that 50% of the servers do not have knowledge, and 50% have some knowledge.

Another important result was observed in the response to the question about services: P3 = Regarding the importance of implementing accessibility services for visually impaired people in BIBCE, do you consider: indispensable, irrelevant, necessary, timely, relevant. In this case, 66.7% responded as indispensable, while 33.3% considered it necessary. Table 1 shows results of the questionnaires.

The focus group technique was applied to evaluate the needs, perceptions and knowledge focused on NBR 9050/2015, to the technicians, being three (3) librarians and three (3) administrative technicians and four (4) visually impairment users, through a checklist addressing issues related to physical structure and technological development of BIBCE. We describe here the most emblematic issues brought as experiences described by technicians and users conforming the everyday of the library.

Knowledgement barriers (A = Student/B = Librarians/T = Technicians)

A2—The visually impaired student reported that the blind person is different from the person who has low vision, people can't tell the difference; it is necessary to sensitize the guidance and training of coordinators and technicians;

B1—The librarian considered that training and information are very important, after answering the checklist, because the basic knowledgement is missing; for example, the NBR 9050 is not known, it is not known what a tactile floor is; there is need for awareness, including managers to articulate through projects, and a trained coordination with information to pass on to employees;

Table 1 Shows results of the questionnaires

Variables	18 respondents %
P1	
Yes	0
Very little	16.7
No	83.3
P2	
Yes	50
I have some knowledge	50
No	0
P3	
Indispensable	66.7
Irrelevant	0
Required	33.3
Appropriate	0
Relevant	0

B2—The librarian points to the general feeling of the group, the lack of information, as the great barrier to care of the visually impaired person in the library;

T1—As a sensitization strategy, the presence of people with visual impairment in the Library was suggested, performing activities, participating in the routines, serving as an example for everyone's learning, observing their limitations in relation to the services offered, as we learned from the coexistence;

T3—The lack of adequacy of the structure was notorious, it would be necessary to have implements for adequacy, but the training is more relevant for sensitization and information, both for the servers and for the visitors to the Library.

Attitudinal barriers

A1—A blind user said that investing in people would be more important than investing in infrastructure. The equipment are essentials, but an informed technician is the key to good service. Being a student of a course at the Center of Arts and Communication-CAC, he also claimed to feel more at ease in the spaces of BIBCE, because technicians have a more inclusive vision;

B1—The librarian considered the need to provoke managers;

B2—The librarian commented that the library system should open a number of internship vacancies in the libraries for visually impaired users;

T2—For the technician, the information would be the main strategy of the group to know how to interact in the everyday, and to sensitize their daily lives with the coexistence;

T3—The coach mentioned that the first barrier to be broken is the attitudinal barrier. At the very least, one needs to study why this happens, there is resistance, but it is mostly due to lack of information. Through colleagues with visual impairment, one learns from the exchange of experiences. From this experience (coexistence) replicates in any situation, in any industry, no matter if it will be as a user or if it will be the server.

Communication barriers

T2—Coexistence is the best action to achieve accessibility.

T3—Hire interns visually impaired, such that we will have the visually impaired as a participant, a staff member, so the team will have to adapt so that it has the same conditions of action to be able to find a book on the shelf, guide a sighted user, if it were the case, to have competence and autonomy, to be qualified for work, then the Library would become reference in attendance. The biggest barrier for me in the University Libraries in attendance, is still the staff, because there is that speech, I do not know how to answer, I do not know how to treat, but the information has to arrive, often the person is resistant, still see many actions as a project, something punctual, still not an institutional thing, this also weighs a lot.

Physical barriers

A2—The student reported that he feels difficulties of going to the library already in the entrance of the Center of Education-UFPE, because there is a tactile floor in the door of the center that does not go until the library. In the library, there was a tactile floor, but no physical structure or spaces adapted for people with disabilities.

T1—The technician said that the library needs more communication, information and basic structure, this would be the best way to discuss mobility issues.

T3—The technician observed that it is necessary to apply what is prescribed in the NBR 9050, but the accessibility is beyond the NBR 9050.

B1—The librarian claimed that lack infrastructure, and training for technicians to support infrastructure.

In the focus group, some emergency needs were detected for the immediate provision of services offered to blind and low vision users:

- Installation of computers adapted for people with visual impairment.
- The horizontal and vertical signs must be carefully designed so that there is autonomy to all the people who attend the library.
- The antenna must be a fully horizontal model, the walking stick does not reach the top of the antenna, causing accidents.

4 Discussion and Conclusion

The reports of the participants of the research were relevant, highlighting the manifestation of their opinions regarding the form and content of the verbal interaction, verified through their speeches.

The results indicate a lack of knowledge on the subject, which factor so that the server does not feel at ease to receive and use any type of equipment, whether adapted or accessible, think of adapted physical structure and even meet the user with visual impairment in the Library.

It was observed through the perception of the participants of the research, the concern to acquire knowledge, through training and daily experiences with people with visual impairment. We call attention to a new phase of the Library, the discovery and proposition of practical alternatives aiming at the achievement of technical competence.

The results were relevant to the creation and development of a character that composes a spelling book, whose main argument is the dissemination of knowledge through the image, offering a new vision in the understanding of the legal norms of accessibility, alerting to the improvement of physical spaces, attitudinal and technological developments.

The services for people with disabilities can be enhanced through the use of new technologies, such as speech synthesizers for the visually impaired [12]. The content of the booklet is well diversified, focusing on assistive technology, strong allied inclusion (Fig. 2).

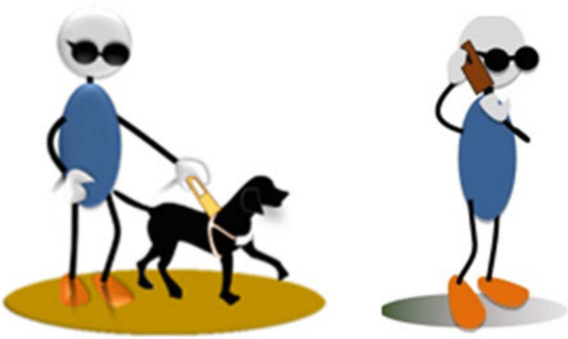

Fig. 2 Proposed illustration for the booklet

It was clear that the person who holds the knowledge is able to change behaviors and assist in decision making, and this is the possible condition for the transposition of the aspects that represent the barriers to the effective participation of people with visual impairment in the various spaces of the BIBCE. The key points of the factors Human Factors in ergonomics, should be specific to an in-formation sustainability [13].

In this sense, we create learning forms that integrate and involve all of the system to achieve the continuous improvement of quality products and services that meet the needs of the visually impaired individual. From the transformation of the conceptual map into a character, it was noticed that an educational primer (see Fig. 3) has a valuable contribution to developing skills and favoring the autonomy of Library staff.

The recommendations to make an Inclusive Library go beyond physical, communicational, and attitudinal barriers. It is knowledge focused on accessibility,

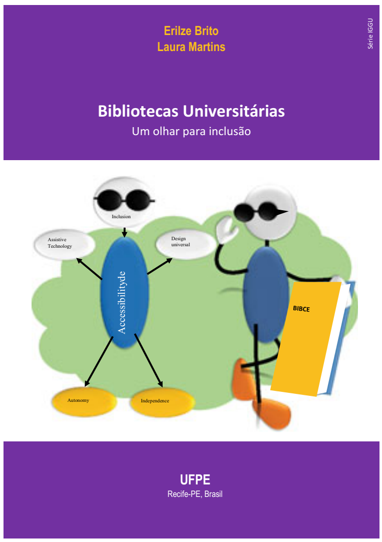

Fig. 3 Cover of the educational primer

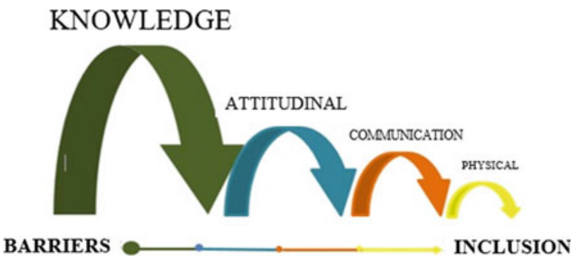

Fig. 4 Accessibility barriers in the library

Fig. 5 Inclusion

involving technicians, librarians and the entire Library system, as a point to be discussed in the development and implementation of new research (see Fig. 4).

It should be noted that there was no exhaustion of the relevance of the theme, further studies should be carried out in order to analyze user satisfaction in a Library environment. The inclusion is a process, not a result, and occurs when individuals feel connected through types of support received from others [14].

Social inclusion (see Fig. 5), is the acceptance of individual differences [15].

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Revisiting Diffusion Models: Portuguese Integrated Management Systems Evolution

Mónica Cabecinhas, Pedro Domingues, Paulo Sampaio and Pedro M. Arezes

Abstract This paper aims to update and report the diffusion and forecasting models of Portuguese integrated management systems (IMSs) encompassing the ISO 9001, ISO 14001 and OHSAS 18001 standards (QES). A research method similar to that described by Cabecinhas et al. [1] was adopted. Data concerning the evolution of the amount of multiple MSs in Portugal (ranging from 1999 to 2016) was retrieved from a periodical Portuguese publication (*Barómetro da Certificação*). The evolutionary behavior of the number of MSs over the years was studied adopting both the Gompertz and the Simple Logistic models. The results obtained by fitting the data to these models were dissected enabling a forecast for the forthcoming years. In opposition to the results of the original study (based on a higher percentage of extrapolated data) the data seem to be properly fitted by the Simple Logistic model. Similarly to the conclusions of the original study the diffusion throughout the years of the number of MSs presents an S-shaped behavior and the Gompertz model predicts a higher amount of IMSs at the saturation level (which is in line with the original conclusions).

Keywords Management systems integration · Diffusion models · Portugal · Gompertz and Simple Logistic models

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1 Introduction

Integrated management systems (IMSs) have been actively, extensively and comprehensively studied by the mainstream research community over the last two decades. However, several research gaps remain unanswered. Recently a joint effort by four research teams from south European countries (including Portugal) unfolded the behavior and forecasted the diffusion of IMSs [1]. This paper intends to test and update the Portuguese diffusion model taking into account the data (now available) from the last years. The paper is structured as follows: The "Literature Review" section addresses and dissects the latest published contributions in the domain of IMSs and diffusion of standardized MSs. The research method is described in the following section and the "Results" section presents and discusses the soundest research outputs. The "Conclusions" section summarizes the results, dissects the implications and points out future research avenues.

2 Literature Review

2.1 Management Systems Integration

As previously stated, the MSs integration topic still has some research gaps that were not yet addressed and/or answered. However throughout the last years several relevant and groundbreaking contributions were reported and published through different streams of bibliography. In a first stream, the soundest benefits attained by companies who implement an IMS, the major expectations and the difficulties faced were extensively reported by several authors. Additionally several integration levels were identified, a great deal of integration strategies were depicted and some specific organizational functions (such as audits) were dissected. Later on, in a second stream of bibliography, integration models and best practices were proposed, concepts revolving around the MSs integration concept were identified, guidelines aiming at a successful integration were reported and patterns identified. In the current stream of bibliography authors address often the maturity of IMSs and how an IMS may be tailored and designed to be in line with concepts such as sustainability, corporate social responsibility (CSR), innovation, risk management, total quality management (TQM) and lean practices. In addition, some recent publications addressed the impact and the financial performance of companies operating with multiple MSs and the diffusion of these multiple certificates at country level.

Table 1 summarizes some of the most recent published studies addressing the phenomenon of MSs integration where one may conclude that authors from around the world are currently engaged in pursuing a particular issue within the broad

Table 1 Latest published studies in the domain of IMSs

Authors	#	Year	Country	Sub-topic
Domingues et al.	[2]	2016	Portugal	IMSs maturity
Dragomir et al.	[3]	2017	Romania	
Moumen and El Aoufir	[4]	2018	Morocco	
Poltronieri et al.	[5]	2018	Brazil	
Nunhes et al.	[6]	2017	Brazil	Integration strategies/frameworks
Chountalas and Tepaskoualos	[7]	2018	Greece	
Llonch et al.	[8]	2018	Spain	
Ezzat et al.	[9]	2017	Egypt	
Jimenez et al.	[10]	2018	Colombia	
Shevchenko et al.	[11]	2018	Canada	
Sui et al.	[12]	2018	China	
Bernardo et al.	[13]	2018	Greece	
Muthusamy et al.	[14]	2018	India	
Muzaimi et al.	[15]	2018	Malaysia	
Gracia et al.	[16]	2018	Colombia	
Nunhes et al.	[17]	2019	Brazil/Spain	
Rebelo et al.	[18]	2017	Portugal	Risk management
Emetumah	[19]	2017	Nigeria	
Gianni et al.	[21]	2017	Greece	CSR
Ionescu et al.	[22]	2018	Romania	
Souza and Alves	[23]	2018	Brazil	Sustainability
Başaran	[24]	2018	Turkey	
Mustapha et al.	[25]	2017	Malaysia	
Hernandez-Vivanco et al.	[26]	2018	Spain	Innovation
Talapatra et al.	[27]	2018	Bangladesh	TQM
Jewalikar and Shelke	[28]	2017	India	Lean integration
Nunhes et al.	[30]	2016	Brazil	Research gaps/literature analysis
Cuevas Castañeda	[31]	2018	Colombia	
Moumen and El Aoufir	[32]	2017	Morocco	
Tuczek et al.	[33]	2018	Austria/New Zealand	
Medina	[34]	2018	Colombia	Integration theories
Martí-Ballester and Simon	[35]	2017	Spain	Financial performance/impact multiple certifications
Hernandez-Vivanco et al.	[36]	2018	Portugal	
Alfredo and Nurcahyo	[44]	2018	Indonesia	
Wiengarten et al.	[45]	2017	Ireland	

(continued)

Table 1 (continued)

Authors	#	Year	Country	Sub-topic
Gurina et al.	[37]	2018	Russia	Sector specific IMS
Gianni et al.	[38]	2017	Greece	
Pal Pandi et al.	[39]	2018	India	
Pratama et al.	[40]	2018	UK	
Pop and Ţîţu	[41]	2018	Romania	Information security/information system/IT issues
Lança and Brito	[42]	2017	Portugal	
Balabanov and Davletshin	[43]	2018	Russia	
Benyettou and Abdellatif	[46]	2018	Algeria	Theoretical model
Arda et al.	[47]	2018	Turkey	Mediating variables
Cabecinhas et al.	[1]	2018	Portugal/Spain/Greece/Italy	IMSs diffusion
Bernardo et al.	[29]	2017	Spain/Greece	Integration patterns
Mjakuškina and Lapiņa	[48]	2018	Latvia	Product conformity
Dahlin and Isaksson	[49]	2017	Sweden	IMS concept
Majerník et al.	[20]	2017	Slovak Republic	ISO 2015 Revision

domain of IMSs. As previously stated, a great deal of these recent studies report tools, methods and models aiming at the assessment of the maturity of IMSs [2–5] and some innovative integration strategies/frameworks and how to proceed with a successful implementation [6–17]. A relevant amount of papers address some emergent concepts and their linkage with IMSs, such as, risk management [18, 19] and the latest standards revisions [20], corporate social responsibility (CSR) [21, 22], sustainability [23–25], innovation [26], total quality management (TQM) [27] and lean management [28]. It should be pointed out that Bernardo et al. [29] identified some similar and dissimilar integration patterns in Greek and Spanish companies, Nunhes et al. [30], Cuevas Castañeda [31], Moumen and El Aoufir [32] and Tuczek et al. [33] analyzed and dissected some of the research gaps in the existing literature, Medina [34] summarized the soundest integration theories and the financial performance of companies operating with multiple certifications was a topic addressed by Martí-Ballester and Simon [35], Hernandez-Vivanco et al. [36] and Llonch et al. [8]. The remaining papers dissected some sector specific issues within IMSs [37–40], the Information/IT requirements to support the resulting IMS [41–43], the impact of multiple certifications [44, 45], some theoretical models [46] and mediating variables of the integration process [47].

2.2 Diffusion of Management Systems Standards

The studies on the diffusion of MSs standards aim at addressing several research questions simultaneously, namely (among others), at which extent the MSs standards will be implemented?; has the saturation stage been reached?; which patterns emerge?; and which diffusion model fits accurately the data available?

The first efforts on the topic of MSs diffusion models were reported by Corbett and Kirsch [50] throughout the latest years of the last century and early years of the new millennium. The last contributions were reported by a joint venture encompassing four European research groups from Portugal, Spain, Italy and Greece and addressing companies holding multiple certifications schemes [1]—Table 2. The published studies focused mainly on the diffusion of different standards and management tools, such as, the ISO 9001 standard [51–65], the ISO 14001 [50, 51, 56, 60, 64, 66–71], Eco-Management and Audit Scheme (EMAS) [72], UN Global Compact [71], the ISO/TS 16949 standard [73], the SA 8000 standard [74], the ISO 22000 standard [75] and the Spanish "Q" standard [52, 65]. It should be pointed out that some of these studies addressed a single activity sector [52, 63, 65, 73, 75], some considered solely selected countries or macro-regions [51, 57, 66, 69, 70, 76], some of them tested and/or reported explanatory factors [50, 59, 61, 68, 77] and some compared between two clusters of companies [72].

3 Research Method

The current work is supported in the same methodology adopted in the paper of Cabecinhas et al. [1] regarding the analysis of the diffusion of companies holding simultaneously certified Quality, Environmental and Safety (QES) MSs. Concurrently, this paper aims at updating the previous reported model considering that its performance is affected by the number of observations collected and by the inclusion of the inflexion point in the range of the variation of the data. This fact demands for a continuous update of the model (fitted through the available data) to check its validity throughout time [1, 79]. So, based on the existing literature, it is assumed that the fitted models follow an S-shaped curve (Gompertz and Simple Logistic curves).

3.1 Gompertz Curve

The Gompertz curve is a widely used model to characterize the S-shape behaviour (Eq. 1) [80–83]. This model is characterized by his asymmetry relatively to the point of inflexion, i.e., this point emerges prior to achieving half of the time needed

Table 2 Latest published studies in the domain of standardized MSs diffusion

Authors	#	Year	Region	Comments	Topic/Standard
Cabecinhas et al.	[1]	2018	Portugal/ Spain/Italy	–	IMS (ISO 9001+ISO 14001+OHSAS 18001)
Hikichi et al.	[66]	2017	American countries	Breakdown by country and activity sector	ISO 14001/ISO 14000
Casadesús et al.	[67]	2008	Selected countries	–	
Corbett and Kirsch	[50]	2001	Worldwide	Report some explanatory factors	
Delmas and Montes-Sancho	[68]	2011	139 countries	Report some explanatory factors	
Hikichi et al.	[69]	2017	America	Breakdown by country	
Qi et al.	[70]	2011	China	Breakdown by province	
To and Lee	[77]	2014	Worldwide/ Regional/ Countries	Report some explanatory factors	
Albuquerque et al.	[51]	2007	Selected countries	Selected countries	ISO 9000/1 and ISO 14000/1
Marimon et al.	[56]	2009	Worldwide	Breakdown by country Decertification phenomenon is dissected	
Viadiu et al.	[60]	2006	Worldwide	Breakdown by activity sector	
Marimón et al.	[64]	2008	Spain/Serbia	–	
Chen and Liu	[53]	2009	China	–	ISO 9000/1
Franceschini et al.	[54]	2010	Europe	–	
Llach et al.	[55]	2011	Worldwide	Breakdown by activity sector	
Salgado et al.	[57]	2015	America	Breakdown by country	
Sampaio et al.	[58]	2009	Wordwide/EU	–	
Sampaio et al.	[59]	2011	Worldwide	Report some explanatory factors	
Grajek	[61]	2004	Selected countries	Relationship with bilateral trade	
Franceschini et al.	[62]	2006	Selected countries	–	
Kale and Arditi	[63]	2006	Turkey	Precast concrete industry	
Alonso-Almeida et al.	[52]	2013	Spain	Hospitality industry	ISO 9001 and “Q” standard

(continued)

Table 2 (continued)

Authors	#	Year	Region	Comments	Topic/Standard
Franceschini et al.	[73]	2011	Worldwide	Automotive industry	ISO/TS 16949
Heras-Saizarbitoria et al.	[72]	2015	Europe	High and low polluting industries	EMAS
Llach et al.	[74]	2015	Worldwide	Breakdown by country and activity sector	SA 8000
Meade and Islam	[78]	2006	–	Innovation(s)	Technologic innovation(s)
Perkins and Neumayer	[71]	2010	Worldwide	–	ISO 14001 and Global Compact
Almeida et al.	[65]	2009	Spain	Hotel industry	Q standard
Mohammed and Zheng	[75]	2016	Worldwide	Breakdown by country Food industry	ISO 22000
Raweni and Majstorovic	[76]	2016	European countries	–	ISO standards

to reach the saturation level [80, 84, 85]. The value ***a*** represents the saturation level, i.e., the maximum number of certified companies that can be expected and achieved

$$y(t) = a.\,e^{-e^{[-k.(t-tc)]}} \quad (1)$$

3.2 *Simple Logistic Curve*

The Simple Logistic curve is one of the most adopted curves in the literature. In opposition to the Gompertz curve the Simple Logistic curve is symmetric to the point of inflexion, meaning that this will occur in the middle of the time needed to achieve the saturation level [80, 84, 85]. Similarly to the Gompertz curve, the value ***a*** represents the saturation level. The simple logistic curve is represented by the Eq. (2) [80–83].

$$y(t) = \frac{a}{1 + e^{[-k.(t-t_c)]}} \quad (2)$$

Detailed information regarding the models can be found in previous works [1, 81, 85, 88–90]. The non-linear least square regression was the approach adopted to fit both curves [83, 85–87].

3.3 Materials

The data sample was collected from the study of Cabecinhas et al. [1] encompassing some additional data from more recent years (2014, 2015 and 2016). Similarly to this previous study, the data was collected through the contact with local certification bodies operating in Portugal that provided their available information regarding the number of certified IMSs (available at *Barómetro da Certificação*). Table 3 presents the data used to analyse the diffusion of the QES.

In this case, the data reflects the evolution of the number of certificates entailing that the decertification phenomenon is also considered. In line with the study authored by Cabecinhas et al. [1] the data used do not consider the level of integration of the MSs implemented meaning that these certificates account for MSs simultaneously certified with, at least, the three more common certified MSs, i.e. the ISO 9001, ISO 14001 and OHSAS 18001 standards.

Table 3 Data used to fit the models

Year	Counter	Nº of QES
1999	1	7
2000	2	12
2001	3	25
2002	4	40
2003	5	77
2004	6	131
2005	7	170
2006	8	199
2007	9	281
2008	10	–
2009	11	347
2010	12	429
2011	13	468
2012	14	577
2013	15	670
2014	16	679
2015	17	569
2016	18	580

4 Results

Both curves were fitted to the data from Table 3. The variable "Counter" was used as an independent variable to identify temporal scale. The parameters obtained for each model are presented in the Table 4. Figures 1 and 2 depict the curves fitted according the Gompertz and Simple Logistic models, respectively.

The results presented in Table 4 suggest that both models properly fit the diffusion of QES in Portugal. However, including the new added data and looking at the residual sum of squares, the Simple Logistic model seems to describe accurately the dynamics of this phenomenon when compared with the Gompertz model. Taking into account the results obtained for the forthcoming saturation level of QES in both models, it is possible to observe a decrease of the expected number of organizations holding simultaneously these MSs in both cases (if one benchmark against the original study). However, the difference for the saturation level of the Gompertz curve is higher than the difference obtained for the Simple Logistic curve suggesting that the Gompertz model experience higher changes than the Simple Logistic curve, so it can be more sensitive to the amount of data needed to get a accurate prediction of what will happen in the future. Like in the previous study, the Gompertz curve seems to predict a higher amount of QES than the Simple Logistic curve at the saturation level.

Table 4 Parameters obtained for each model

Curve parameters	Gompertz	Simple logistic
a	735.29	662.59
xc	8.85	10.09
k	0.22	0.40
Degrees of freedom	14	14
Residual sum of squares	29733.73	25976.07
R-square	0.97	0.97

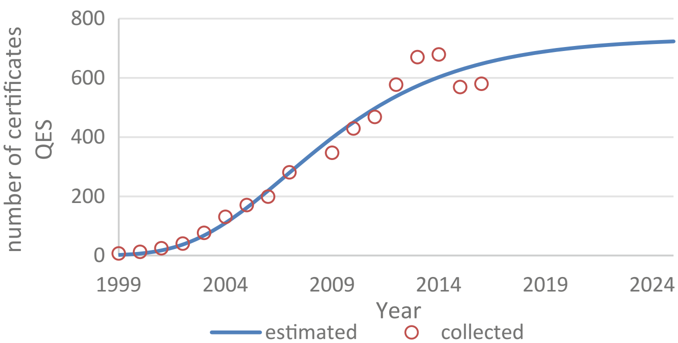

Fig. 1 Gompertz curve (Portugal)

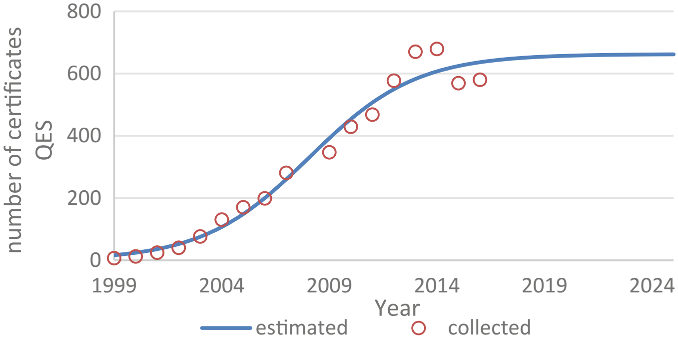

Fig. 2 Simple logistic curve (Portugal)

5 Conclusions

This study aimed to update the work developed by Cabecinhas et al. [1] taking into account more recent data. In addition, intends to dissect the forthcoming trend of the diffusion of IMSs. The presented study shows the fluctuations that could happen in the process of analyzing the diffusion of IMSs, highlighting the importance of the update process of these kinds of studies since, the more recent data added could result in huge chances when compared with the more incomplete data set. The actual update showed differences in the saturation levels predicted and in the model that describes accurately the phenomenon. These differences could result from the revision of the standards, since ISO 9001 standard and ISO 14001 were revised in 2015. It would be of great interest to analyze the impact of the new editions of the standards in the diffusion of the IMS and the development of a model that could explain what generally happen in times of transition of the standards. It was also possible to observe that the Gompertz model seems to have a more positive view of the future of the IMS. For the second time predicts a saturation level higher than the Simple Logistic model. Some shortcomings can be identified in this study like the consideration of companies that presented the three management system standards "simultaneously certified" and not actually integrated, so the level of integration of the standards is not assessed or considered in this study.

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Occupational Safety and Health in Solar Home Systems (SHS) by Brazilian Standards

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Abstract The use of renewable energy in Brazil has increased due to the possibility of reducing the environmental and economic impacts. Therefore, the solar energy has been used around the country due to its economic and environmental advantages, also because of the governmental support through incentives and tax benefits. One of the ways to generate energy through solar radiation is the Solar Home Systems (SHS), which comprise a solar panel to convert sunlight available in the top of the buildings into useful electrical energy. However, the installation and maintenance of SHS present risks and hazards to the workers and users, especially because the activities are done at heights and falling is one of the greatest causes of death by work. This is why it is so important to provide measures to avoid or reduce harms. Hence, the present paper aims to analyze the risks regarded to the installation, operation and maintenance of SHS and the measures recommended by the Brazilian standards to nullify or mitigate those. To achieve this goal, a descriptive and exploratory bibliographical review was carried out. Finally, it was observed the importance of the safety at height and in electrical activities such as the Solar Home System (SHS) operations, as the number of accidents is still high in Brazil. Therefore, it is necessary to know all the available standards documents to ensure all the safety measures are taken, to comply with all system requirements, and to protect the health and well-being of the employee and employer.

Keywords Solar home system · Construction safety · Occupational safety · Solar panels · Photovoltaic energy

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1 Introduction

Due to the increase of energy consumption, the economic growth, the reduction of energy resources and the concern about environmental impacts, alternative means of clean and renewable energy have been encouraged, such as solar and wind energy [1].

Solar energy was introduced in the Brazilian energy matrix in 2010 with the capacity of 1 Megawatts, increasing to 24 Megawatts in 2016 [2]. Evidently, there has been an expressive growth, and the tendency is to keep increasing due to governmental incentives as tax benefits and direct and indirect subsidies. Moreover, the country has advantages to produce this energy because of its high quartz deposit, which is the source to produce the silicon by purification, the main material of solar panel [3].

The photovoltaic system is composed of a generator, a power conditioning block and, optionally, a storage block. The module consists of connected photovoltaic cells to produce satisfactory voltage and current to the use of energy [4]. Photovoltaic systems are classified according to the type of energy generation or transmission, which can be: isolated systems or systems connected to the grid [5]. Their cells are manufactured from crystalline silicon, which corresponds to approximately 80% obtained from the quartz that must be purified to a high level, about 99.99% of purity; and the remaining 20% made of thin films [3].

One of the ways to generate energy through radiation is the Solar Home Systems (SHS), which are a solar panel to convert sunlight available in the top of the buildings into useful electrical energy, a battery to storage the energy whenever there is no radiation and a device to manage the charging and discharging of the battery [6].

The advantages of the SHS are the inexhaustible source, the zero emission of pollutants during the generation of electricity, the flexibility for its installation, among others. However, there are a few disadvantages such as the variation of solar radiation availability of the place and the high financial resources to capture and convert energy compared to conventional systems [5].

According to Moscardini Júnior [7], the installation of a photovoltaic system requires professionals from many areas of engineering and architecture. The operation and maintenance of these generators require a greater multidisciplinary knowledge, necessary for planning and understanding of the procedures and their intervention periodicity, indispensable to keep them functioning properly. This process may lead the workers to some risk if safety measures are not being followed [8].

According to the Brazilian Statistical Yearbook of Occupational Accidents [9], in 2017, 549,405 accidents were registered. In this year, the number of deaths caused by occupational activities was 2096, which decreased 6.59% from 2016 to 2017. Moreover, accidents that caused worker permanent disability also reduced 18.4%. In 2016, 17,914 people received some financial support related to work accidents. Regarding harms related to electricity, Abracopel [10] presents that the number of deaths caused by shocks, fire and lightning were 1387. The fatal electric shock accidents are about 627 records and almost 35% of this number took place in habitations. Therefore, the number of injuries in occupational activities is very high, and measures should be carried out to avoid them.

Despite the high number of accidents and injuries in occupational activities related to electricity and height, there is no significant number of researches in Brazil that points out the risks related to Solar Home Systems (SHS). Besides, it is worth to know that, there are two types of Brazilian standards related to the nullification and mitigation of those risks, the technical (NBR) and the regulatory (NR), and only the latter is obligatory. Therefore, this paper aims to present the risks regarded to the installation, operation and maintenance of SHS and the measures recommended by a survey of Brazilian standards. To achieve this goal, a descriptive and exploratory bibliographical review was carried out. According to Prodanov and Freitas [11], the descriptive research is an observational method, not interfering in the recorded facts, and the exploratory is indicated whenever a subject is in the preliminary phase. It is hoped that this work will contribute to the dissemination of knowledge about SHS work safety.

2 Occupational Safety and Health in Solar Home Systems (SHS)

The photovoltaic energy systems have many advantages such as their great simplicity, modular characteristic and high reliability. Besides, they produce energy close to the consumer, do not occupy extra area and do not cause environmental interference on surroundings [12]. However, according to Oliveira [13], as any electricity generation system, it must fulfill quality and safety requirements.

In the design stage, some measures must be taken to predict some system criteria, and then provide greater safety to the user and the worker. Initially, it should be considered the base for the photovoltaic systems support and fixation on the top of the building, considering the overweight caused by the mass of the solar array and the workers during interventions, in order to avoid structural collapses or failures. Moreover, it should be noted the possible wind loads, as well as the thermal movements [14]. There are Brazilian standards documents to all of these recommendations, such as ABNT NBR 6118 [15] Design of concrete structures, and in case of other types of materials, ABNT NBR 7190 [16] Design of wooden structures and NBR 8800 [17] Design of steel and composite structures for buildings.

The SHS requires periodic maintenance [14] and it is necessary to provide ways to facilitate this operation. The standard NBR 15.575 [18]—Residential Buildings Performance recommends requirements to achieve the maintainability and the capacity of the building and its systems to allow the inspections and maintenance activities.

Related to SHS electrical installations, the criteria recommended by the standard ABNT NBR 5410 [19]—Electrical installations of buildings—low voltage must be obeyed. According to Rüther [14], the SHS is different than the conventional system, as it is energized whenever there is a light on and its current is direct. The standard ensures that, if the conditions are complied, the safety of people and animals, the prevention of damage to the environment, and the proper functioning of the installation are guaranteed. In the document, there is an item specifically about security, divided in protection against:

(i) electric shocks;
(ii) thermal effects such as burns, fires, etc.;
(iii) overcurrent;
(iv) overvoltage and electromagnetic disturbances;
(v) voltage drops and faults.

In SHS installation and operation stages, safety and accident prevention measures are also necessary, which are directly related to occupational medicine and safety. The Brazilian regulatory standard NR 35 [20]—Working at Heights is very important for this type of work, as the number of accidents caused by falling is greater than electric shocks in Brazil. According to the data from the Digital Observatory of Health and Occupational Safety [21], from 2016 to this day, 2969 fall accidents happened, specifically from roofs, and 67 deaths were registered. The NR 35 [20] considers work in height any activity performed above 2 m of the lowest level, which has a falling risk. SHSs are generally located in roofs and rooftops, and usually present hazards to the worker at interventions. The document presents items that must be fulfilled to avoid occupational accidents, such as:

(i) employer and employee role and responsibilities;
(ii) employee training provided by the employer;
(iii) planning and execution done by skilled worker;
(iv) fall protection systems that must be used whenever it is not possible to avoid working at height, always providing the collective and personal protective equipment;
(v) emergency and rescue personnel, trained and provided by the employer.

The standard 35 also refers to others NRs: NR 6, NR 7 and NR 18. The first one, NR 6—Personal Protection Equipment (PPE) [22–24], is about the devices used by the workers for hazard protection. The Personal Protective Equipment (PPE) helps to prevent accidents such as cuts, burns, scratches, electric shocks, among others. It is used whenever it is impossible to use a Collective Protection Equipment (CPE), which is preferable, or to complement it. For Takahashi et al. [25], workers in some industries, such as construction, have some resistance to safety measures and present a high rate of rejection to PPE use. For the author, the workers are aware the risks are not eliminated by their use, but their function is to minimize them. Hence, this insufficiency makes the safety hazards to be assumed individually by the laborer.

Moreover, related to SHS installation and operation, NR 18—Working Conditions and Environment in Construction Industry [24] recommends the installation of CPEs in places that present a falling risk besides the PPE for work at height. In addition, another role is to promote and preserve the health of these workers, as recommended in the NR 7—Occupational Health Examination Programs [23]. Therefore, periodic medical examinations related to the type of activity are required [26]. Exams are necessary to work at heights to avoid accidents caused by health problems such as labyrinthitis, dizziness, fainting, etc.

Finally, to guarantee the minimum health and safety requirements of workers engaged in activities related to electricity, there is the regulatory standard NR 10—Safety in Electrical Installations and Services [27]. It is applied in several stages such as the generation, transmission and distribution of energy, and includes even the design, installation and maintenance stages. It presents measures to avoid harms related to electrical energy such as shocks, burns, fires, among others. It should always be associated with the SHS standard document, the NBR 16274 [28]—Grid connected photovoltaic systems.

An analysis was carried out relating the SHS risks, to whom they are related, the Brazilian standards that guide and recommend measures of mitigation or nullification of these, and what preventive actions should be taken. The results are shown in Table 1.

Table 1 SHS risks analysis

	Risk	Standard	Prevention
Building and its users	Structural collapse or failure caused by overweight from the panels and workers	NBR 6118—Design of concrete structures [15]/ NBR 7190 (1997) Design of wooden structures [16]/ NBR 8800 (2008) Design of steel and composite structures for buildings [17]	Predict the additional loads related to the mass of the photovoltaic system and the workers during installation/operation
	Structural collapse or failure caused by wind loads	NBR 6123—Wind Loads [29]	Predict the loads due to the wind in buildings
	Presence of fragile elements on the rooftop/roof	Not applicable	Specify suitable materials for installation, operation and maintenance of photovoltaic systems
	Hazard in maintenance due to lack of	NBR 15575—Residential Buildings—Performance [18]	Design the building to provide access conditions for

(continued)

Table 1 (continued)

	Risk	Standard	Prevention
	specifications to carry it out		inspections such as supports to fix elements to enable maintenance (scaffolding)
	Insecurity to people and animals and damage to built assets caused by electrical installations	NBR 5410—Electrical installations of buildings—Low voltage [19]	Present conditions to satisfy low-voltage electrical installations criteria in order to ensure the safety, the correct functioning of the installation and the preservation of built assets
SHS workers	Objects falling, cuts, scratches, shocks, burns, etc.	NR 6—Personal Protective Equipment (PPE) [22]	Provide Personal Protection Equipment for hazard protection
	Fainting, loss of balance, dizziness, etc.	NR 7—Occupational Health Examination Programs [23]	Establish the obligation to elaborate and implement the Occupational Health Examination Program (Programa de Controle Médico de Saúde Ocupacional) to promote and preserve the health of the employee
	Electrical shocks, burns and fires	NR 10—Safety in Electrical Installations and Services [27] NBR 16274—Grid connected photovoltaic systems [28]	Establish minimum requirements and conditions to implement preventive measures in order to guarantee the safety and health of those who interact to electricity
	Falling, winds, rain, lightning	NR 18—Working Conditions and Environment in Construction Industry [24]/NR 35—Working at heights [20]	Establish minimum requirements and protective measures for work at heights, involving planning, organization and execution

3 Conclusions

Due to the increase of energy consumption and environmental issues, renewable energy sources are attracting the attention of researches; therefore, solar energy is one of the most environmentally viable options. In Brazil, despite the high potential of solar irradiation, this technology is still not widespread, but it has been increasing over time and even more with governmental incentives.

To implement the Solar Home System (SHS), skilled professionals are needed, from planning to execution stages. Hence, it is important to ensure safety measures prescribed by Brazilian standards to mitigate or nullify the hazards. It is necessary to aware the worker of the PPE and CPE use when installing the solar system. Besides, working at heights is one of the main causes of accident, and it may result in loss or reduction of the capacity of the worker or even death.

The survey of the Brazilian standards provided the prevention measures, aiming to minimize the number of accidents and to contribute with knowledge for the professionals, engineers or architects, about technical procedures. As it was shown in Table 1, there are several NBRs and NRs to guide the installation process of SHS, whether about the structure, the performance or environmental actions; as well as about the safety and workplace conditions.

As a suggestion for future studies, it would be interesting to evaluate the influence of the publication of the regulatory standards (NRs) on the number of accidents to find out if there was a decrease or not. Moreover, studies in situ should be carried out to verify the application of the safety measures.

In conclusion, it was observed the importance of the safety at height and in electrical activities such as the Solar Home System (SHS) in Brazil, since the number of accidents is still high. Therefore, it is necessary to know all the available standards documents to ensure all the safety measures are taken, to comply with all system requirements, and to protect the health and well-being of the employee and employer.

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Ageing at Work: Capacity for the Work of ESTeSC Teachers

T. Correia, H. Simões, J. Pereira, E. Telo, T. P. Cotrim, J. Figueiredo and A. Ferreira

Abstract Aging does not necessarily mean a decrease in "ability to work" and that the eventual decline of certain skills related to increasing age are not generalizable, striking, or uniform and can be accelerated or delayed depending on the conditions of work, individuals and, above all, the types of attrition to which the worker is subjected (Sato et al. in Processo de envelhecimento e trabalho:estudo de caso no setor de engenharia de manutenção de um hospital público do Município de São Paulo, Brasil, 2017, [14]). To evaluate the work ability index (WAI) of the professors of the School of Technology and Health of Coimbra (ESTeSC). This study was an analytical observational and prospective cohort study. The respondents answered a questionnaire that assessed the WAI and the quality of life index (QLI). The results were evaluated in the IBM SPSS Statistics program through descriptive character tests and inference tests. It was verified that an average value of 33.63 (7–49 scale) was identified for the work ability in the studied group, being this value belonging to the Moderate category. When correlating the age of workers

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with WAI and QLI, it was verified that there was no correlation ($p > 0.05$) between these factors. On the other hand, WAI was related to QLI, in which a correlation was observed ($p < 0.05$), that is, the more satisfied they are with quality of life, the better the capacity for work. It was found that in the present study, aging does not cause a loss of capacity for work, nor does it influence the quality of life of workers. Since teachers' scores for WAI are in the Moderate category, it is necessary to implement health promotion strategies, such as practicing physical exercise or performing work-related gymnastics in the workplace.

Keywords Aging at work · Age · Ability to work · Quality of life

1 Introduction

The aging of the working population is a frequent theme in modern societies, where the number of people over the age of 50 tends to increase in the coming decades [2]. Aging does not necessarily mean a decrease in "ability to work" and that the eventual decline of certain skills, related to the increase in age, are not generalizable, striking, or uniform, and can be accelerated or delayed depending on the working conditions, the individuals and, above all, the types of attrition to which the worker is subjected [1]. The forecasts by the European Agency for Safety and Health at Work (EU-OSHA) indicate that in 2030, 30% of the active population of most European countries (including Portugal) is between 55 and 64 years old [3].

There are particularities of aging related to the activities that people exercise, which must be taken into account, in the search for an understanding of this process [4]. The education professional develops one of the most important activities of society. In addition to requiring time-off for student training and commitment to the tasks of class preparation, the teaching work includes performing administrative services of the pedagogical practice, building plans and school projects, and evaluating students academic outputs. The performance of these activities requires good physical and mental health because it requires great physical and psychic efforts [5]. Recent studies have evidenced an increase in the number of health-related injuries of teachers with consequent impairment of their work capacity [6]. The World Health Organization (WHO) has shown concern about the issue of work-related aging and recognizes that changes occur in the various systems of the human body that lead to a gradual decrease in the effectiveness of each of them, with a decrease in the functional capacity of individuals which can generate conflicts between the functional capacity and the demands of the work [7]. The physical and mental health of any worker is a determining factor for the capacity to work [6]. Fifty years ago the WHO challenged the traditional design of health centered on its physical dimension and absence of disease and went on to define health as "a complete state of physical, mental and social well-being, and not merely the absence of disease or infirmity" [8]. The conceptual definition of capacity for work is the question of how well the worker is now and in the near future and how well he is fit to do his job relation to the demands of work, health and mental resources [9]. Maintaining work capacity involves adequate health and work conditions, whether in interpersonal or environmental relationships. It is important to emphasize that in this way, this will translate into a better quality of life inside and outside work and greater productivity [10]. Age does not necessarily determine a reduction in work capacity, but it means greater diversity in the way workers deal with the demands and in the type and degree of adequacy of their responses [11].

According to the literature, the concept of quality of life emerged at the beginning of the twentieth century directed to the life conditions, including at work, and the effects in the individuals. The quality of life is the perception of the subjects about their position before society, permeated by their culture, values and everyday life and with a view to their goal and life expectancies and ways of thinking about their life [12]. The Quality of Life Index (QLI) is an indicator that can measure the quality of life in terms of satisfaction with life subjectively emphasizing the perception of satisfaction/ importance that the various aspects of everyday life are exposed to the individual itself [13].

Therefore, as the workforce grows older, it is essential to develop measures for disease prevention and health promotion in work situations, seeking the preservation and development of capacities and maintenance of the quality of life inside and outside work [14].

2 Materials and Methods

2.1 Study Design

The present study was carried out in the 2017/2018 school year and data collection was performed be-tween February and June 2018. This study was presented as level II, of the analytical observational type and of the prospective cohort.

2.2 Population and Sample

The target population was the professors of the School of Technology and Health of Coimbra (ETeSC). The type of sampling was non-probabilistic and the technique was for convenience. The inclusion criteria were: the teachers were in the age group between 28 and 62 years old and were teachers of the ESTeSC. The total number of teachers participating in this study would be 130. However, the sample obtained in this study was 46.

2.3 Instruments and Data Collection

Data collection was done through the completion of a questionnaire, which included a first part with sociobiographical information, a second part related to the work ability index (WAI) was done through the Portuguese version of the 2006, Portugal and PALOPs, and a last part referring to the quality of life index (QLI).

The WAI is an instrument built on 10 items that are composed of several issues, which consider diseases, physical and mental demands of work. These items constitute seven dimensions, each evaluated by one or more questions. The calculation of the global scale takes into account the sum of the points received for each of its items [15]. The ability to work compared to the best of all life varies on a scale of 0–10, Ability to work in relation to physical requirements ranges from 2 to 10, Number of current diseases diagnosed by the doctor ranges from 1 to 7, Estimated loss for work due to illnesses ranges from 1 to 6, Failures to work due to illnesses in the last year (12 months) ranges from 1 to 5, Prognosis of ability to work within 2 years varies between 1, 4 or 7 and Mental resources range from 1 to 4. The larger the global WAI scale, the better the workers' ability to work.

The QLI in this study was used as an indicator that seeks to measure the quality of life in terms of life satisfaction in a subjective way, being this adapted for the general population (generic version III). The first part was based on the level of satisfaction of the respondent in the various domains of life or are-as, and the items are presented on a Lickert scale ranging from 1 "very unsatisfied" to 6 "very satisfied". The second part focused on the degree of perceived importance of the respondent in these same areas or domains of life, and the items are also presented on a Likert scale ranging from 1 "no importance" to 6 "very important". This index is evaluated both globally and in four dimensions: Health and Functionality, Social and Economic, Psycho-logical and Spiritual and Family, giving a total of 33 items [13]. In order to estimate the scores, each item of satisfaction should be weighted by its importance correspondent, which allowed us to affirm that the highest scores represent high satisfaction and high importance and the lowest satisfaction low but high importance. The estimation of scores was guided by the principle that people who are satisfied with areas they consider important enjoy a better quality of life than people who are dissatisfied with areas that they consider important [16]. Regarding the reliability of the items, the internal consistency was analyzed, producing the following results: for the value of the "Health and Functionality" index, with 13 items, presented a Cronbach's Alpha of 0.901; "Psychological and Spiritual", composed of 7 items, presented a Cronbach's Alpha index of 0.894; As for the "Social and Economic" dimension, with 8 items, presented a Cronbach's Alpha index of 0.832 and the last "Family" dimension, composed of 5 items, revealed a Cronbach's Alpha index value of 0.835.

2.4 Statistical Analysis

Statistical analysis of the collected data was performed using the IBM SPSS Statistic version 25 software for Windows 7. Using this software, it was possible to use descriptive statistics such as location (average) and dispersion (standard deviation) measurements. The tests used were the Wilcoxon nonparametric test and the Pearson Linear Correlation Coefficient test.

2.5 Ethical Issues

All data collected was used solely for academic purposes, and was not disclosed for other purposes other than that previously mentioned, without any financial or economic interests. The completion of the questionnaires had the consent of the chair of the ESTeSC, being informed about the objectives of the study, always maintaining the anonymity of the answers obtained.

3 Results

3.1 General Characterization of the Sample

Observing Table 1, it was verified that the majority of the respondents, of both the feminine and the masculine gender were married and had Masters. Regarding the ages, it was observed that the age of the participants in the study ranged from 28 to 62 years, and the total mean age was 44.37 years. However, it was observed that the mean was identical in both the female (44.41) and the male (44.29).

3.2 Inferential Analysis

After data collection it was found that an average value of 33.63 (7–49 scale) was identified for the ability to work in the studied group. Regarding the WAI classification (Table 2), two of the respondents presented a poor work capacity index (7–27), thirty-seven of the individuals presented a Moderate scale (28–36) and the remaining seven participants in the study entered the Good category (37–43), with none of the teachers meeting an excellent work ability index (44–49).

According to Table 3, we can verify that there was no correlation between the teachers age and their perception of their ability to work ($p > 0.05$). We also found that there was no correlation between the age of teachers and the index of work

Table 1 Sociobiographic characterization of teachers of ESTeSC

		n	Female %column	n	Male %column	n	Total %column
Civil status	Unmarried	5	15.6	3	21.4	8	17.4
	Married	19	59.4	10	71.4	29	63.0
	Unity of fact	5	15.6	0	.0	5	10.9
	Separated/ divorced	3	9.4	1	7.1	4	8.7
	Total	32	100.0	14	100.0	46	100.0
Literary abilities	Graduation	5	15.6	0	.0	5	10.9
	Master	13	40.6	8	57.1	21	45.7
	Doctoral	11	34.4	6	42.9	17	37.0
	Post Doctoral	3	9.4	0	.0	3	6.5
	Total	32	100.0	14	100.0	46	100.0
		M	SD	M	SD	M	SD
Age		44.41	7.16	44.29	9.60	44.37	7.87

Legend 1 N = Sample number; M = Mean; SD = Standard deviation

Table 2 Work ability index

		N	%
WAI	Poor	2	4.3
	Moderate	37	80.4
	Good	7	15.2
	Total	46	100.0

Legend 2 N = Sample number; % = Percentage

Table 3 Relationship between age, WA-Perception and WAI

N = 46		Age	WA-perception	WAI
Age	r	1	0.098	−0.042
	p		0.518	0.780
WA-perception	r		1	0.778
	p			<0.0001
WAI	r			1
	p			

Legend 3 N = Sample number; WA-perception = Teachers perception of capacity for current work; WAI = Work ability index

ability calculated through the results obtained in the questionnaires. However, we can observe a positive correlation pattern between the participant's perception of ability to work and the capacity to work index as an objective measure ($p < 0.0001$). We can also add that this pattern of agreement was verified in 61% of the respondents under study.

Looking at Table 4, we try to evaluate the number of years that the worker presented in the institution and how this indicator would be related to both the subjective measure and the objective measure of the capacity for work. We found that there was no relation between the number of years of work and the measures for work capacity under study ($p > 0.05$).

After analysis of Table 5, it was verified that the majority, that is, 26 of the respondents had a good perception of their ability to work with regard to mental and physical demands.

According to the mental requirements, it was observed that 16 of the teachers classified their perception of their ability to work as Very good, and the remaining 4 participants in the study considered it Moderate. Regarding the physical requirements, 13 of the respondents rated the perception of their ability to work as Very Good, and the remaining 7 as Moderate.

We can verify that none of the teachers considered their perception of their ability to work as Weak or Very weak relative to mental and physical requirements.

According to Table 6, in relation to WAI and QLI, we found a correlation pattern between the indices ($p < 0.05$). We can verify that the objective measure of the Evaluation of Work Capacity correlated positively with both the General Quality of Life index and the respective sub-dimensions of this last indicator. We

Table 4 Relationship between number of years in institution, WA-perception and WAI

N = 46		WA-perception	WAI
Number of years in institution	r	−0.060	−0.211
	p	0.690	0.158

Legend 4 N = Sample number; WA-perception = Teachers perception of capacity for current work; WAI = Work ability index

Table 5 Relationship between perception WA of mental and physical requirements

		n	%	% cumulative
Perception WA of mental requirements	Very good	16	34.8	34.8
	Good	26	56.5	91.3
	Moderate	4	8.7	100.0
	Total	46	100.0	
Perception WA of physical requirements	Very good	13	28.3	28.3
	Good	26	56.5	84.8
	Moderate	7	15.2	100.0
	Total	46	100.0	

Legend 5 WA = Capacity of work

Table 6 Relationship between perception WA and QLI

N = 46		WA-perception	Health and functionality	Social and economic	Psychological and spiritual	Family
WA-perception	r	1	0.302	0.420	0.379	0.285
	p		0.041	0.004	0.009	0.055
Health and functionality	r		1	0.647	0.642	0.793
	p			<0.0001	<0.0001	<0.0001
Social and economic	r			1	0.653	0.751
	p				<0.0001	<0.0001
Psychological and spiritual	r				1	0.603
	p					<0.0001
Family	r					1
	p					

Legend 6 N = Sample number; WA-perception = Perception of capacity work; QLI = Quality life index

can affirm that workers with greater capacity for work were also the same workers who present a better perception of health status, in general, as well as health, functional, social, economic, psychological/ spiritual and family.

In relation to the WA-Perception and the WAI, we could observe a correlation pattern among the indexes ($p < 0.05$). We can verify that the objective measure of the Evaluation of the Capacity for Work correlated positively with both the General Quality of Life index and the respective sub-dimensions of this last indicator, except with the sub-dimension "Family". We can affirm that workers with greater perception of the ability to work were also the same workers who presented a better perception of health status, either in general, or in terms of health, functionality, social, economic and psychological/spiritual. Relative to the Family and the perception for the capacity in the work it is verified that there was no correlation ($p > 0.05$). When analyzing Tables 7 and 8 together, we can verify that the p-value is higher when it relates the Health and Functionality and the Family with the WAI than when it relates to the WA-Perception. Regarding the Social and Economic and Psychological and Spiritual levels, the opposite happens to what was mentioned previously, since when relating these factors with the WAI, lower values were obtained than when compared to the WA-Perception.

4 Discussion

Based on the scales obtained from each worker's self-assessment of their ability to work through the Work Ability Index, it was verified in the present study that the professors of the Coimbra School of Technology and Health have a mean scale of WAI of 33.63 points, indicating moderate capacity for work. According to Sérgio Junior, if the ability to work is moderate, it is recommended to encourage worker initiatives to promote their capacity [15]. Kelly Alves, states that the strategies used by the teacher to mitigate losses and facilitate their adaptation to the new phase include the struggle to pre-serve their own identity, which is a psychological problem experienced in aging [4].

In the present study, the average age of the respondents was 44.37 and it was found that there is no relation between the age of the workers and the loss of capacity for work. In a previous study, Elaine Marqueze & Claudia Moreno stated that the variable age did not correlate with WAI, that is, having an older age did not imply a lower capacity index [17]. On the other hand, epidemiological studies verified the association of age with early loss of ability to work [9]. Some authors point out that age affects the ability to work for the individual, especially from the age of 45, because the factors that lead to the decrease in the capacity to work begin to accumulate [18].

With regard to “current work ability, compared to its best”, that is, individuals’ perception about their ability to work, ranged from a scale of 5 to 10 points. Kelly Alves, mentions that participating teachers express the idea that teaching as work is an ‘antidote to aging’ at the level of one’s own perceptions [4].

Regarding “work capacity in relation to the requirements of the activity”, a large part of the participants in the study, that is, 25 of the respondents stated that the main demands of their work activity are mental, 10 of the teachers indicated both requirements, and only one of the participants noted physical requirements. Regarding perceived ability to work in relation to mental demands, 34.8% indicated Very Good, 56.5% as Good and 8.7% as Moderate. Regarding physical requirements, 28.3% considered Very Good, 56.5% as Good and the remaining 15.2% as Moderate. Given the answers previously mentioned, Marilú Martins, says that the positive perception of the workers regarding the demands in the work, can be related to the experience in the work, emphasizing the freedom and the sense respect, being added of an improvement in the life outside the work, good relationships with col-leagues, leadership, solidarity and trust [19].

It is important to note that most of the teachers at ESTeSC have been on average for about 13 years at the same institution, but that there was no correlation with their ability to work. Studies carried out with public employees, who had physical work demands, had the capacity to work diminished over the years, due to the organization and work environment [10].

With regard to diseases, 26.1% of the study participants reported that they did not have any type of disease or injury, the remaining 73.9% mentioned at least one disease or injury. According to studies, from the age of 45, with the appearance and/or aggravation of several types of diseases, physical and mental functional capacity may begin to deteriorate, influenced by the decrease in cardiorespiratory and musculoskeletal capacity as a function of age [20]. As for injuries resulting from accidents, 17.4% of the population studied reported that suffer from spine/ back. With regard to musculoskeletal injuries, 13.0% indicated that they suffer from back/ neck disorders, with frequent pain. Maria Martinez & Maria Latorre, report that cardiorespiratory capacity and musculoskeletal functioning are the aspects that have the greatest impact on functional capacity [21]. Studies indicate that biomechanical factors involved in physical work demands, among them strength, repetitiveness and inadequate postures, have a great relation with the promotion of musculoskeletal injuries [22]. 17.4% indicated as respiratory disease, chronic sinusitis/rhinitis. 13.0% of teachers stated that they suffer from mild mental disturbance (such as mild depression, nervousness, anxiety, sleep disturbance). Luciano Pereira & Giancarlo Zille, consider stress as a state in which there is an abnormal wear of the human organism, causing a reduction in its capacity to work [23]. The previous authors also affirm that stress is a great concern, being directly related to workers health and the productivity of organizations [23]. 17.4% indicated that they suffer from an Endocrine and Metabolic Disease, such as Goiter or other Thyroid disease. Regarding the other diseases implicit in the questionnaire, there was no great representativeness.

Regarding the “Estimation of the degree of incapacity for work due to illness”, more than half of the respondents, that is, 54.3% indicated as an answer “I have no limitations/I have no disease”, 26,1% said “I can do my job but it causes me some symptoms”, 15.2% stated “Sometimes I have to slow down my work or change the way I work”, and the remaining 4.3% mentioned “I often have to slow down my work or change the way I work”. According to the WAI development methodology, workers who have a greater number of diseases tend to have the capacity for impaired work. To counteract what was said, a study carried out in São Paulo with municipal workers showed that a greater number of diseases implied a decrease in the value of the WAI, besides the physical and mental capacity and impediment to work [10].

When analyzing “Absenteeism during the last year”, it was found that 41 of the participants in the study did not miss a day to work due to health problems. The remaining 5 teachers were only missing a maximum of 9 days of work. As for the “Prognosis of working capacity for two years from now”, the answers were positive, with 5 respondents responding “Maybe” and the remaining 41 “Almost certainly”. In a similar study, Elaine Marqueze & Claudia Moreno, cite that, of the teachers studied, they did not associate the cited aspects as negative influencers of their capacity for work, since most reported a positive prognosis his ability to work in two years time [17]. Overall, as far as “Psychological resources” are concerned, most positive responses were obtained. Regarding the appreciation of day-to-day activities, only 8.7% indicated “Rarely” and 2.2% “Never”. As for the fact that they felt active, the majority were satisfied, with only 2.2% responding “Rarely” and another 2.2% “Never”. Concerning optimism about the future, the majority were also satisfied, since only 4.3% of respondents indicated the response “Rarely”. In order to emphasize the above, Cristiane Andrade and Maria Moneiro affirmed that the questions regarding the mental resources, in general, presented themselves with positive perspectives, in regard to feeling alert and active, able to carry out daily activities and with hope for the future [10].

It was found that workers quality of life correlates with their ability to work, that is, the more satisfied they are with their quality of life, the better their ability to work. Dayane Queiroz and José Souza, confirm what was mentioned previously, the higher the WAI, the higher the QLI scales [24]. In studies that approach the teaching work, a variety of factors related to the teaching-learning process can be perceived that can interfere in teachers quality of life and health [25]. According to the present study, it was found that Health and Functionality are the factors that present the highest correlation with the WAI. However, according to the workers perception of their ability to work, they considered that the factor that has the greatest correlation with the WAI is the Social and Economic factor. On the other hand, we observed that the Family factor is the one that has a smaller correlation with the WAI and even with the perception that workers have about their capacity for work. Second, Elaine Marqueze & Claudia Moreno, satisfaction in the exercise of teaching work can increase the capacity for the professional of this area [17]. Mariana Monteiro, Susana Paixão, João Figueiredo & Ana Ferreira, point out that the way each one assesses their health will tend to vary depending on how they deal with the challenges and adversities they will encounter throughout their life cycle [13].

5 Conclusion

The conclusions we reached with our study allowed us to understand that age is not always related to functional aging and loss of capacity. However, other indicators may be determining factors for assessing the ability to work, such as the diseases and injuries of workers and the requirements they are exposed to. On the other hand, we can verify that the quality of life influences the capacity for work, since the more individuals are satisfied about their Health and Functioning, Social and Economic, Psychological and Spiritual and Family, the better their capacity for job.

It should be noted that the promotion of occupational health is one of the fundamental aspects in maintaining the capacity for work. For health promotion, strategies should be developed, such as performing work gymnastics and devoting a little of their time in day to day exercise. Practicing workout consists of stretching, muscle relaxation, and flexibility of the joints, which is an important workplace strategy that can prevent repetitive strain injuries. Physical Education can act in the promotion of workers' health, identifying problems in the relationship between overload and work capacity, structuring strategies for the balance of these relationships [26]. The regular practice of physical exercise benefits physically, socially and mentally the entire population, regardless of gender and age; being a promoter of better mental health, well-being and quality life [27].

Faced with the factors studied, it will be important in the future to emerge in new research trajectories, which may take into account other factors. The ide-al would be to repeat the assessment of work ability periodically and to analyze the possible changes over the years and to associate the mental health of the workers with the capacity of work and the quality of life, since after the analysis of several studies it was verified that stress and anxiety are one of the factors that most influence the capacity for work and the quality of life.

Regarding the limitations of this study, we verified that it was not possible to obtain the sample initially studied, due to the difficulty of adherence to participation in filling it.

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Analysis of Industry 4.0 Technologies Applied to the Health Sector: Systematic Literature Review

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Abstract The health sector is possibly the sector most in need of an adequate technological convergence of factors of the Fourth Industrial Revolution. Health 4.0 can be understood as the set of technological procedures emerging from the physical, biological and digital worlds that seeks to improve the efficiency and effectiveness of health processes and professionals with guidelines for transforming data into useful and accessible information. However, systematizing and qualitatively describing the contributions of industry 4.0 in the context of the health sector is a complex task. This article presents an analysis of industry 4.0 related to the health sector and their descriptive characteristics. As a complement, it discusses the perspectives for the greater use of technology in the health area. In methodological terms, a Systematic Bibliographic Review was applied in the context of industry 4.0 with emphasis on terms referring to health issues in two international databases (Science Direct and ISI Web of Science). The research is classified as descriptive and qualitative, of an exploratory nature. As a result, the main technologies that are part of Health 4.0 have been identified in the literature and should be adopted to avoid future problems with patients. The results obtained contribute to narrowing the gap of information about industry 4.0 in the health sector.

Keywords Industry 4.0 · Health 4.0 · Emerging technologies

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1 Introduction

Industry 4.0 is combined with intelligence in data processing [1]. The recently proposed concept of Industry 4.0 represents the fourth industrial revolution, which is defined as a new level of organization and control over the product lifecycle value chain, with an emphasis on customer requirements that become more individualized [2]. The term “Industry 4.0” emerged in Germany in 2011 through the integration between associations of business representatives, politicians and academic researchers who sought to promote the idea as an approach to strengthen the competitiveness of German manufacturing industry [3] and bridging the boundaries between the digital, physical and biological worlds [4].

In health, the principles of Industry 4.0 incorporate the digitization of clinical, medical and laboratory data, implementing the automation of several manual processes used in hospital and general health environments [5]. However, services in the health sector always present challenges, since different diseases can be developed over the years [6]. Thus, to improve the efficiency and speed of physicians, to explore patient data in hospitals, to enable optimization of resources and to minimize deterioration of the patient’s health [7], real-time communication technologies [8], Big Data, human-machine cooperation, remote sensing, process monitoring and control, stand-alone equipment and interconnectivity [9] are becoming very active and responsible for positive impacts on health and safety management [10].

In this context, the term “health 4.0”, developed by the Aliança Brasileira da Indústria Inovadora de Saúde (ABIIS) stands out from the characteristics of industry 4.0, which proposes an interaction between technology and human beings in the health sector. In Health 4.0, the possibilities of collaborative partnerships among actors in the same value chain, who can share the coordinated planning of production and distribution, in an agile and effective way to the needs of users, are facilitated. The work is developed with adequate inventories to avoid delays or unavailability of products and there is a fast response to the demands of the end users and an efficient control in the transaction of patient data in hospitals [11]. However, understanding how to perform data digitization, interconnectivity between machines and commands, more efficient databases, and, in particular, greater autonomy of patients in relation to their own health is a complex task [12].

Exploring technology-driven initiatives that make life easier for human beings will be a research trend. Thus, this article presents an analysis of industry 4.0 related to the health sector and their respective characteristics in Brazil. As a complement, this research seeks to verify the perspectives for the use of technology in the health area. It should be emphasized that although the study presents an analysis of industry 4.0 in the health sector, it is not the objective of the research to define rigorously the semantics and syntax of the Brazilian context. The proposed results of the analysis demonstrate which perspectives should be adopted in the health sector, facilitating the dissemination of knowledge regarding Health 4.0.

The main contribution of the article to the literature is the identification of qualitative and exploratory health variables for an analysis and adaptation of technologies that can be used in hospitals. The propositions and reflections raised did not contribute to subsidize the scientific research on the subject, which can give continuity to this study.

2 Methodology

To carry out the initial stage of the research, it was necessary to develop the formulation of the research problem and its delimitation of context, focused on the interface between industry 4.0 and the Brazilian health sector. The general and specific objectives of the work were then elaborated. In the third stage, the theoretical study was made. To carry out the theoretical part of the research, the method of Systematic Literature Review (SLR) was selected. The SLR methodology uses as a data source the existing literature on a given theme, selects and evaluates contributions, analyzes and synthesizes data [13]. In addition, it describes the evidence in order to allow clear conclusions about the topics that are already known, as well as what is unknown about the subject matter [13, 14]. The analysis (fourth stage of the research) is characterized as theoretical-conceptual and objective to present the main technologies that contextualize health 4.0, in order to analyze their descriptions.

The scope of the literature review includes articles published in journals and journals that deal with the context of industry 4.0, with emphasis on aspects related to the health sector. The databases used were Science Direct and ISI Web of Science due to the breadth of these bases and relevance to the areas of knowledge covered by this research (industry 4.0, health 4.0, healthcare, health technologies and related areas). To perform the advanced searches in the databases, it was necessary to make use of logical operators. Subsequently, it was necessary to establish the keywords (without quotes and without refinement by area of knowledge) to be used in the theoretical survey in the databases. After the searches, the refinement of the survey considered the period between 2011 and 2018 in the databases. The search procedure was carried out between June 20 and July 10, 2018. Only papers written in English and documents such as "article", "review" or books and book chapters were selected.

The keywords used by the authors fall into the following two categories: (i) industry-related keywords 4.0, such as: industry 4.0, cyber-physical systems, Cloud Computing (CC), Internet of Things (IoT); and (ii) health related keywords such as: health, smart hospitals, Smart Healthcare, Healthcare Services. For the files available in full, it was necessary to perform a complete reading and their references were observed to ensure that other works have not been detected in the original survey. After applying the filtering based on the previously explicit criteria, 178 articles were identified.

The articles that had only relation with the industry 4.0 in the title were excluded, for a total of 105. Subsequently, the abstracts that considered the established terms were evaluated and 30 other papers were excluded, which emphasized the concept of industry 4.0 and did not mention the health sector. Finally, another filtering was carried out with emphasis on the introduction and conclusion, being excluded respectively another 33 works. Thus, 10 research papers were selected as containing more details about the technologies of industry 4.0 that are being used in health.

The research sought to select different approaches of the technologies, with the purpose of demonstrating the evolution and the progress of the health sector from research in universities and companies. In addition, it sought to present the state of the art and analysis of gaps of different levels of integration components, analyzing different proposals existing in the literature.

3 Results

3.1 Industry Technologies 4.0 Used in the Health Sector

Technological innovations have driven the health sector to an unprecedented level. Different medical devices, many of them portable, are being sold in the consumer market to provide a healthier lifestyle for society [15]. Some of the technologies relate to Cloud Computing (CC) and Internet of Things (IoT). These are platforms that provide alternatives to medical support through the solution of various problems in health applications, with intelligent hospitals, drug control and remote medical services [6, 8]. In addition, with cyber-physical systems, they can interconnect with a combination of softwares, sensors, processing and communication technologies that together play an important role in decision making by providing accurate and momentous information [3].

With the interconnection of hospitals, people and systems provide real dynamics with optimized time and self-organized with respect to the patient's condition. Industry 4.0 technologies that present similarities in the use of the health sector should also develop new paradigms on occupational health and safety management, as safer equipment is needed to operate and work environments and practices with better control and management [10]. For Chang [16], another technology that should facilitate the exploration of areas that can not be easily reached by traditional means of medicine is computational intelligence, which includes simulations of genes and proteins related to the development and immunity of cancer.

As in the context of industry 4.0, the literature does not present a unique way of naming health technologies 4.0. The classifications used in the literature are often incompatible with each other, since they classify the same technologies into different categories [17]. As a way of contributing to this diversity of health technology classification 4.0, this work uses the functionalities of technologies as a way of categorizing them. In Table 1 are the main technologies found in the literature that contemplate the principles of industry 4.0 and that are commonly used in the health sector. To facilitate the understanding, it was necessary to present the

Table 1 Technologies developed in Industry 4.0 used in the Health Sector

Authors/ year	Technology	Description	Objective	Countries	References
Pang et al. (2013)	Internet ofThings (IoT)	Home health services based on IoT to solve problems caused by population aging	Propose a business-technology developed in co-design that realizes an integration of devices and services of home health attention	Sweden	[22]
Trinugroho et al. (2014)	Internet ofThings (IoT)	Support IOT-based communications between devices and health services in an event-driven manner	Describe the platform developed, with emphasis on reliability aspects, including availability, scalability and security	Norway	[15]
Catarinucci et al. (2015)	Internet ofThings (IoT)	Identification by radiofrequency, wireless sensor network and intelligent mobile technologies of patients' physiological parameters	To propose a new intelligent architecture, with IoT recognition, for automatic monitoring and tracking of patients, people and biomedical devices inside hospitals and nursing institutes	Italy	[23]
Zhang et al. (2015)	Wearable Devices and Smartphones	Continuous monitoring of health conditions, remotely diagnose phenomena and share health information in real time	Investigate the security and privacy protection of multifunctional wearable devices and the widespread use of smartphones, including aggregation of privacy data that preserves privacy, secure health data processing, and detection of misbehavior	Canada	[20]
Darwish et al. (2017)	Cloud Computing (CC) e Internet of Things (IoT)	The integration of technologies provides a solution to various problems in health applications, drug control and distance medical services	Present a new concept of CC and IoT integration for health applications (CloudIoT-Health)	Egypt	[6]
Elhoseny et al. (2017)	Cloud Computing (CC)	Intelligent systems based on cloud environment for hospital health services	Improve scheduling of tasks and reduce stakeholder engagement time (patients, doctors, nurses, for example) and maximize resource utilization in clouds	Egypt	[5]

(continued)

Table 1 (continued)

Authors/ year	Technology	Description	Objective	Countries	References
Pramanik et al. (2017)	Big Data e Smart Healthcare	Big Data and Smart Healthcare systems independently attract great attention from the academia and industry and can streamline healthcare industry perspectives	Evaluate Big Data technologies and intelligent systems focusing on state-of-the-art advanced health systems	China	[24]
Costa et al. (2018)	Internet of Health Things (IoHT)	Intelligent monitoring of vital signs on hospital wings through IoT	Describe the possibilities of IoT in the scope of vital signs monitoring by hospital wards	Brazil	[7]
Mshali et al. (2018)	Health Monitoring Systems (HMS)	Provide timely electronic health services for individuals who wish to maintain their independence	Present a review of intelligent health monitoring and health care systems for individuals, especially for the elderly and dependent	France	[25]
Rahmani et al. (2018)	Internet of Things (IoT)	Develop health solutions with smarter and predictive capabilities for both daily living (home/office) and hospitals using IoT and the strategic position of such gateways	Explore the concept of Cloud Computing in Healthcare IoT systems, forming an intermediate layer of intelligence distributed geographically between the sensors and the cloud	USA	[26]

description of each technology to verify its function and, from the objective of this article, what they seek to improve in the hospitals and in the health topic in general.

4 Discussions

According to Liang [18] there are other devices such as wearable ones that are developing widely and can be used to provide continuous medical care, such as monitoring of physiological parameters for health care through remote monitoring. These are wristwatches, bracelets, rings and smart haircuts that fit as ubiquitous products and use mobile networks (WIFI) and computer servers that are responsible for collecting health information detected by such products [18–20]. In addition, they process the data to properly monitor and diagnose integrity and allow social interactions with users, so that no errors result [20, 21].

For Costa [7], patient data are collected manually in hospitals from stand-alone medical devices, including vital signs. Such data are sometimes stored in electronic spreadsheets, not being part of patients' electronic records, and therefore it is difficult for those in the hospital to combine and analyze. Thus, one solution to overcome these limitations is the interconnection of medical devices via the Internet using a distributed platform, IoT. This approach allows data from different sources to be combined to better diagnose the patient's health status and identify possible anticipatory actions [7].

According to Elhoseny [5], the adoption of the CC and IoT paradigm in health can significantly improve health services and contribute to their continuous and systematic innovation in a Big Data environment as industry applications 4.0. However, the resources required to manage this data in a Cloud-IoT environment are still challenging. In addition, connectivity and the analysis of information are the major pillars of this future transformation. Connectivity because the patient will carry all his medical history with greater data security, which is allowed by the blockchain, the same that brought Bitcoin to life. And information analysis because an artificial intelligence makes it possible to process information much faster than a human being. This repetition of comparisons allows the evaluation between causalities to respond in a preventive way to a patient at risk. Understanding the variables that signal an increased patient risk is only possible with this intelligence at hand.

5 Conclusion

The objective of this article was to present an analysis of industry 4.0 related to the health sector and their respective characteristics. As analyzed in the research, in the health sector, health technologies should be adopted that include the principles of industry 4.0 to improve data digitization, interconnectivity between machines and commands, more efficient databases and, health. The main technologies identified in the literature and also in the interviews refer to the CC and IoT developed for hospitals, as they seek to support communication between devices and health services.

In addition, the article contributed to health professionals seeking to better understand definitions and concepts related to health 4.0, also providing researchers and stakeholders with a study on the subject. The description of the results was focused and critical, structured, as far as possible, for the expansion of knowledge about industry 4.0, given its relevance and relevance in the health sector, which are necessary to perform the interconnection of hospitals, people and systems to provide real dynamics with optimized time and self-organized with respect to the patient's condition.

As future steps, it is suggested to carry out research that deepens the field of health knowledge 4.0, such as: (i) analyze how developed countries are developing the health value chain 4.0; (ii) verify how the development of products by Brazilian companies in the health sector should be in the coming years; (iii) conducting a case study in a hospital that covers all the characteristics of a 4.0 industry; and (iv) identify how smart hospitals are empowering employees, while increasing new technologies annually in the control of patient data.

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A Comparison of ISO 2631-5:2004 and ISO 2631-5:2018 Standards for Whole-Body Vibrations Exposure: A Case Study

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Abstract Agricultural tractor drivers are exposed to high level of vibrations during different activities. Continued exposure to Whole Body Vibration (WBV) may cause musculoskeletal disorders and degenerative changes in lumbar spine. This study analyses the WBV transmitted to drivers associated to a typical operation with agricultural tractor. This measurement was based on the models defined in ISO 2631-5:2004 and ISO 2631-5:2018. The study had been carried out in order to make a comparison between the Standards. The R factor (defined in the ISO 2631-5:2004 to estimate the lumbar spine response acceleration), and Ra factor (defined in the ISO 2631-5:2018 to estimate internal spinal forces, ISO 2631-5:2018) were calculated to predict adverse effects in the lumbar spine. In this case study both standards provide similar assessment, low probability of an adverse health effect.

Keywords WBV · Agricultural-tractor · ISO 2631-5:2004 · ISO 2631-5:2018

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1 Introduction

Professional vehicle operators are often expose to whole-body vibration (WBV) and mechanical shocks [1, 2]. Agricultural off-road vehicle operators are exposed to higher levels of WBV which occurs when the tractor is operating [3]. The main points for transmission of WBV to drivers is through vehicle seat-operators interface and cabin floor [4, 5]. Tractors are used in several operations due to its versatility [6]. Most often, tractor performance different tasks over irregular surfaces and with high speed and such circumstances influence the magnitude of the vibrations transmitted to the operator [7].

Previous epidemiological studies have related the long term WBV exposure with musculoskeletal disorders, such as sciatica, low back pain and degenerative changes in the lumbar spine [8, 9]. Since agricultural tractor operators are exposed to multiple shocks WBV for prolonged periods of time, an assessment to limit this exposure is needed to protect workers' health and safety, risk that may arise from this exposure.

The International Organization for Standarization (ISO) published a series of voluntary standards for evaluation of human exposure to WBV. In order to prevent negative health outcomes derivate of mechanical shocks was published the ISO 2631-5:2004 [10]. The ISO 2631-5:2004 standard develops a method to quantify health risks associated to the lumbar spine as consequence of the WBV exposure. This standard has recently been revised and the ISO has published a new Standard: ISO 2631-5:2018 [11]. In contrast to the previous standard, the new assessment model takes into account posture, body mass and height of the operators during the exposure.

In this context, the present study has two objectives. First, predicted health risk associated to a typical operation, performance with agricultural tractor, based on both criteria. Second, a comparison of both standards in an effort to determine if both criteria predict similar health risk.

2 Methodology

2.1 Equipment

A triaxial accelerometer housed in a semi-rigid disc (SV38, Svantek) was used to measure vibration transmitted to the seated operator through the seat surface. The sensitivity of the accelerometer was 100 mV/(m/s^2) at 15.915 Hz, and the measurement range was 0.1–100 Hz. The signal was sampled at a rate of 6000 Hz and stored in a data logger SV106 (Svantek) connected to the accelerometer. Then, the signals were downloaded to a computer and analyzed with Matlab software (MathWorks, Natick, MA, USA). The used instruments meet the ISO 8041-1:2017 [12], ISO 2631-5:2004 [10] and ISO 2631-5:2018 [11] requirements.

2.2 Selection of Operator and Test Measurement

For the experiment, it was chosen a male with 40 years of experience in the agricultural sector and 30 years as tractor operator (see physical characteristics in Table 1).

The operation analyzed was selected after consultation with the operators, in order to determinate the activities containing most shocks and high level of WBV. The test included a work cycle with the tractor during operations with tillage implements in an olive grove. The operator informed that he started exposure when he was 20 (in 1975) and he performs this activity 4 h/days for 150 days per year. The driver posture was classified as group 3 (ISO 2631-5:2018). The exposure pattern per day in all years was constant.

2.3 Selection of Vehicle

The agricultural tractor used to develop the tests has a power of 110 cv. The vehicle weighted 4.2 t (including the cab), with 2.73 m high and 2.20 m wide. It was chosen due to the fact that it is 10 years old and maintenance has been carried out according to the manufacturer's recommendations.

2.4 Measurement of WBV

Measurement duration includes a complete work cycle. The driver was asked to perform the activity under normal conditions. The duration of measurements was enough to ensure that the signal recorded is representative of exposures. The operator was seated in an upright position and did not lose contact with the seat during the data collection.

2.5 Data Collection Procedure

According to the ISO standards, the sign of acceleration signals was correctly recorded (y-axis is positive to the operator's left, x-axis is positive to ventral and z-axis is positive to cranial) and synchronously acquired in all directions.

Table 1 Worker's characteristics for the study

Operator	Age	Height (cm)	Weight (kg)
1	60	178	72

2.6 Analysis of WBV Exposure

The signal collected at the operator/seat interface was used to determine both rms and Crest Factor in order to characterize the acceleration signal. The analysis was carried out in accordance to ISO 2631-5:2004 [10] and ISO 2631-5:2018 [11].

The unweighted rms_k accelerations were calculated by Eq. (1), rms_k is the unweighted *rms* acceleration, T is the signal duration and $a(t)$ is the unweighted acceleration at time t in the k-directions.

$$rms_k = \left(\frac{1}{T}\int_0^T a_k^2(t)\right)^{1/2} \quad \left(\mathrm{m/s^2}\right) \tag{1}$$

Crest Factor (FC_k) were calculated by Eq. (2), where rms_k is the unweighted rms acceleration for each axis in the period T and $Peak(a(t))$ is the absolute maximum instantaneous peak value of the acceleration in the period T.

$$FC_k = \frac{Peak(a(t))}{rms_k(a(t))} \tag{2}$$

ISO 2631-5:2004. The acceleration data were used to calculated adverse health effects in the lumbar spine related to multiple shocks vibration exposure. The model described in this standard estimates the lumbar spine x- and y-axes response acceleration by a single-degree-of-freedom (SDOF) lumped-parameter model. The z-axis acceleration was down-sampled to 160 Hz and the response of the lumbar spine was calculated using a recurrent neural network model.

This information was used to calculated the acceleration dose, D_k, in each direction as defined in Eq. (3), where A_{ik}^6 is the *ith* peak of the response acceleration $a_{lk}(t)$ in the x-, y- and z-axes. The standard defines the peak value as *the maximum absolute value of the response acceleration between two consecutive zero crossings*. For the z-axis only the compressive (positive) peaks were counted.

$$D_k = \left(\sum_i A_{ik}^6\right)^{1/6} \left(\mathrm{m/s^2}\right) \tag{3}$$

The average daily dose, D_{kd}, was calculated according to Eq. (4), where t_d is the duration of the daily exposure and t_m is the period over which D_k has been measured.

$$D_{kd} = D_k \left(\frac{t_d}{t_m}\right)^{1/6} \left(\mathrm{m/s^2}\right) \tag{4}$$

Daily equivalent static compression dose, S_e, for each exposure day is calculated using Eq. (5) where D_k is the acceleration dose in the k-direction, and m_k are different values recommended for each axis.

$$S_e = \left(\sum_{k=x,y,z} (m_k D_k)^6\right)^{1/6} \quad (\mathrm{MPa}) \tag{5}$$

The daily equivalent static compression dose, S_{ed} (Eq. (5)) and the Risk factor (R, Eq. (6)) were used to make the health risk assessment. The S_{ed} was obtained by normalizing D_k to D_{kd} for the average daily exposure. R is defined in Eq. (6), where N is the number of exposure days per year, i es the year counter, n is the number of years of exposure, c is a constant representing the static stress due to gravitational force (the standard recommend $c = 0.25\,\mathrm{MPa}$), S_{ui} is the ultimate strength of the lumbar spine for a person of age $(b+i)$ years (Eq. (7)) and b is the age at which the exposure starts.

$$R = \left(\sum_{i=1}^{n}\left(\frac{S_{ed} \cdot N^{1/6}}{S_{ui} - c}\right)^6\right)^{1/6} \tag{6}$$

$$S_{ui} = 6.75 - 0.066(b+i) \tag{7}$$

ISO 2631-5:2018. This Standard estimate internal spinal forces for two different exposure regimes. One is termed the severe conditions regime (exposure where operators lose contact with the seat surface and are dominated by accelerations in the z-directions) and the other one is for less severe conditions (exposure without free-fall events and where the subjects remains seated throughout the measurements). Both methods are based on the calculation of the daily compressive dose S_d^A and the Risk factor (R^A).

In order to determinate which method has to be used, the measured time series in z-direction at the operator had been checked: after applying the band-limiting filter (defined in ISO 2631-1, two-pole filters with Butterworth characteristic, high pass: corner frequency 0.4 Hz; low pass: corner frequency 100 Hz) the peak acceleration shall not exceed 9.81 m/s^2 for the use of the less severe conditions regime. If the peak acceleration exceeds this value, the severe condition regime should be applied.

The method for less severe conditions requires obtaining the acceleration signals in three axes measured on the seat surface. The feet, backrest and hand acceleration can be also included in the model. In this study, the acceleration measured on the seat surface has been used for the seat and backrest. The forces (compression and shear) in the lumbar spine were calculated by means of transfer functions which depend on the posture, body mass and body mass index of the exposed individual. The transfer functions were derived from the results of a group of finite elements models of the seated human.

The method estimates the compressive dose S^A (MPa), Eq. (8) per exposure for every disc level, where $C_{dyn,i}$ (N) is the sum of peak compressive forces acting on the area of a vertebral endplate B (mm^2) and i stands for the year counter.

$$S^A = \left(\sum_i \left(\frac{C_{dyn,i}}{B}\right)^6\right)^{1/6} \tag{8}$$

The equivalent daily compressive dose of the lumbar spine S_d^A (MPa), Eq. (9), where S_j^A is the dynamic compressive stress of the lumbar spine due to vibration exposure to condition j, t_{dj} is the time period of the daily vibration exposure to condition j, t_{mj} is the time period over which S_j^A has been measured.

$$S_d^A = \left(\sum_j S_j^{A6} \cdot \frac{t_{dj}}{t_{mj}}\right)^{1/6} \tag{9}$$

The risk factor R^A (Eq. (10)) for every disc level was defined for use in the assessment of an adverse health effect related to the daily compressive dose $\left(S_d^A\right)$, where N_i is the number of exposure days per year, i is the year counter, n is the number of years of exposure, S_{ui}^A is the ultimate strength of the lumbar spine for a person of age $(b+i)$ years (Eq. (11)) and $\mathrm{S}_{stat,i}^A$ is the mean value of the compressive-decompressive force divided by the area of vertebra endplate B (mm^2).

$$R^A = \left(\sum_{i=1}^{n} \left(\frac{S_d^A \cdot N_i^{1/6}}{\mathrm{S}_{ui}^A - \mathrm{S}_{stat,i}^A}\right)^6\right)^{1/6} \tag{10}$$

$$\mathrm{S}_{ui}^A = 6.765\,\mathrm{MPa} - 0.067\,\mathrm{MPa} \cdot (b+i) \tag{11}$$

Health Guidance Caution Zone (HGCZ). Both standards define the same boundaries for probable health effects derived from multiple shocks vibration exposure (Table 2). The results obtained are then compared with the boundaries.

Table 2 ISO 2631-5:2004 and ISO 2631-5:2018 assessment of adverse health effects

Probability of an adverse health effect	ISO 2631-5:2004		ISO 2631-5:2018	
Low	S_{ed} < 0.5 MPa	R < 0.8	S_d^A < 0.5 MPa	R^A < 0.8
Moderate	0.5 < S_{ed} < 0.8 MPa	0.8 < R < 1.2	0.5 < S_d^A < 0.8 MPa	0.8 < R^A < 1.2
High	0.8 MPa < S_{ed}	R > 1.2	0.8 MPa < S_d^A	R^A > 1.2

3 Discussion and Results

Once measurement data have been obtained, it is possible to calculate the rms and Crest Factor (Table 3).

The band-limiting filters described in ISO 2631-1 were applied to the measured times series in z-axes. As the peak accelerations obtained did not exceed 9.81 m/s^2 ($MaxPeak(a_z(t)) = 6.58$ m/s^2), the less severe conditions regimen (ISO 2631-5:2018) was applied.

Table 4 shows the results obtained for WBV assessments of ISO 2631-5:2004 and ISO 2631-5:2018. The evolution of R and R^A over the year are shown in Fig. 1 (the most unfavorable R^A value of the vertebral levels has been used to analyses the evolution).

In this case, the acceleration levels measured in the x- and y-axes were significantly greater than in the z-axis. It is due to the irregular surface and the inability of the tractor suspension system to attenuate high amplitude acceleration at low-frequency in x- and y-axes [13]. Nevertheless, the quantitative criteria for determination which method had to be used in ISO 2631-5:2018 is only based on the z-axis.

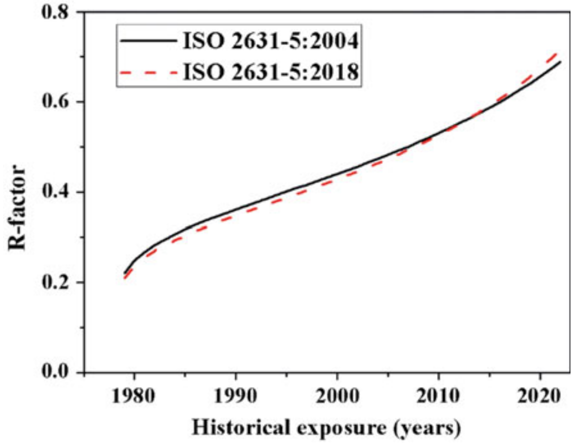
Table 3 Crest Factor and rms values

Heading level	Axes	rms (m/s^2)	Crest Factor
WBV	x	1.18	10.22
	y	0.97	15.06
	z	0.85	7.74

Table 4 ISO 2631-5:2004 and ISO 2631-5:2018 assessments

ISO 2631-5:2004		ISO 2631-5:2018		
S_{ed} (MPa)	R	Disk levels	S_d^A (MPa)	R^A
0.49	0.69	T12/L1	0.40	0.64
		L1/L2	0.41	0.67
		L2/L3	0.43	0.69
		L3/L4	0.44	0.71
		L4/L5	0.43	0.70
		L5/S1	0.40	0.63

Fig. 1 Evolution of R and R^A over the historical exposure (year)



The assessment of the health risk coming from ISO2631-5:2018 estimates the internal spinal forces for each vertebral level. Furthermore, the model takes into account the driver's anthropometries characteristics (such as body mass, height, and posture), age and his pattern exposure over the years. However, ISO 2631-5:2004 defines a different model to estimate the lumbar spine response and only considers the age of the driver in the assessment.

The results obtain of this case of study show that the R value is lower than the R^A. The R factor is 0.69 and R^A varied between 0.63 and 0.71 in the different disk levels. The probability of an adverse health effects is low.

4 Conclusion

This study allowed to expand the knowledge about the ISO 2631-5:2004 and ISO 2631-5:2018, in application to operations with agricultural tractor with tillage implements in olive grove.

Drivers who perform off-road activities with agricultural tractors are exposed to a high level of WBV. The z-axis is not always the predominant in these activities. The new ISO 2631-5:2018 defines two exposure regimes based on the magnitude of z-direction acceleration. If the maximum peak value on each axis exceeds 9.81 m/s^2, the severe conditions regime shall be used and the x- and y- directions are neglected. However, as x- and y- axes peaks are higher than z-axis ones in off-road activities, and so their contribution could be significant in a detailed assessment.

The R factor (ISO 2631-5:2004) obtained is lower than the R^A value (ISO 2631-5:2018). Nevertheless, both standards provided the same assessment: low probability of an adverse health effect. Although the methods studied in this study provided a similar assessment, more measurements becomes necessary in order to include others factors such as the driver's behavior, surface or speed on a more detailed assessment.

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The Importance of Understanding and Mitigating the Risk of Flooding of the Tâmega River in the City of Amarante

Silvia Gomes and Paulo Oliveira

Abstract Over the centuries, Amarante suffered several episodes of flooding due to its morphological characteristics. Amarante is located in a depression area, and the Tâmega River passes alongside the historic center. These specific characteristics hamper the efforts to mitigate the damages arising from episodes of flooding (Costa in O risco de inundação na cidade de Amarante (Norte de Portugal): contributo metodológico para o seu estudo, Revista Territorium n.º 16, pp. 99–111 (2009b) [6]). The main purpose of this work is to evaluate how the residents and the shopkeepers in the city center perceive and minimize the consequences of flooding. In addition, we aim to present a database of residents and shopkeepers on this issue and to understand their plans to tackle this problem in the future. Consequently, this work wishes to promote measures, to support projects that aim to reduce the losses of the population of Amarante and to develop proposals to prevent the flooding in the high-risk areas. The methodology used consisted in the collection of information through a structured questionnaire, including a pre-test, composed of structured and unstructured questions. We use the *SPSS Statistical Package for the Social Sciences* to analyze the data collection. This article also compiles several documents, listed in the references, related to the identification of the main problems experienced by the population. Furthermore, based on the results of the surveys, we created a Manual of Good Practices (MGP) and a group of volunteers to assist the shopkeepers and/or residents (in the removal of furniture/products, among others).

Keywords Tâmega river · Urban floods · Flood mitigation

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1 Introduction

Dramatic occurrences of flooding events across the world create significant damage to buildings and infrastructures and can be a life-threatening natural disaster. Understand the causes and propose prevention measures to mitigate this problem is of great importance to the areas at risk.

Europe has been developing a set of guidelines to minimize the adverse effects arising from these events. Directive 2007/60/EC of 23 October 2007 establishes a framework for the assessment and management of the risks associated with flooding. It refers that the damages can be harmful to the human health, the environment and to the economic activities [7].

Throughout its history, Portugal has suffered devastating effects caused by floods, and more frequently by the flash floods (rapid flooding of geomorphic low-lying areas: washes, rivers, dry lakes and basins), due to the characteristics of the precipitation in the country [4].

Amarante has been no exception and the first records of these occurrences date to the seventeenth century. The highest points registered happened during the twentieth century (1909, 1939 and 1962) and, more recently, in the twenty-first century (2001).

There are several possible causes for the occurrence of these events in Amarante, namely: There are no obstacles to the penetration of air from the sea, which affects the precipitation behavior in this area (Monteiro 2001, quoted by Costa [5]). The very rainy winters, the intensity of the precipitation combined with the saturation of the land and the natural underground reservoirs, increase the difficulty of the water infiltration, favoring the flow [6]. The geomorphological characteristics of the Tâmega river basin and the local flow conditions, which allows the rapid rise of the water level. In Amarante, the pillars of the bridge known as Ponte Nova create significant bottlenecks in the section of the river flow during the flood peaks. The urban occupation along the adjacent areas, particularly visible on the left bank of the river, is also a problem [2]. The steep curves of the river, originated by tectonic causes, as well as the existence of the Frades Island in the middle of the river [3]. The climatic conditions of the area where Amarante is located. The city is located behind the mountain known as Serra do Marão [5].

For these reasons, the reduction of the damage caused by the floods can be done using measures to restructure the riverbanks and the flows. Defenses such as levees, bunds, reservoirs, and weirs are used to prevent rivers from bursting their banks. Measures used during and after the floods are also extremely important. Some examples are: warnings, evacuations and the restoration of the damages [6].

Warning and alerting the population living or working in the high-risk areas are particularly relevant in the event of intensely localized precipitations. In these cases, the time for intervention is extremely short [1].

The main goal of this study is to evaluate the perception and the mitigation of the risk of flooding by the residents and shopkeepers on the riverside zones, in the center of Amarante. This article tries to understand how they have been affected by these episodes, how they mitigate the damages and how they expect to mitigate them in the future. Additionally, it aims to promote the implementation of support measures and projects to help tackling this problem in Amarante.

2 Empirical Approach

The methodology used in this article is divided into four different parts.

In the first part, several scientific documents and legal documents were studied, in order to identify the main difficulties experienced by the population and the evolution of these problems over the years. This allowed us to both understand and identify what has been studied in the literature related to the topic and what is still missing.

The second part's goal was to collect information through a structured survey, using a pre-test, composed by structured and unstructured questions. The questionnaire was composed by 30 questions and included a pre-test. Firstly, it intended to evaluate the characteristics of the sample (gender, age, schooling level, type of building, time living/working in the area). Secondly, it covered the perception and mitigation of the flooding risk of the respondents (number of times that they were affected, which year caused more damages to them, magnitude of the damage, perception of the water level of each flooding, classification of the respondent's risk exposure, insurance coverage, whether they were helped removing their belongings from the affected areas, their knowledge about the contribution of the Municipal Civil Protection Services and of the Firefighters, as well as, their concerns about future floods). The pre-test was made to the Municipal Civil Protection Services and to the Corporations of Volunteers and Firefighters, who have a wide experience in the issue. Only 10 out of 26 entities answered the survey, which represents a percentage of 38.5% of compliance to the survey. However, this percentage is higher than the initially established target of 15–20% defined as essential for a satisfactory validation of the pre-test. The scale used was the Likert's scale that goes from 1 to 6, 1 being "bad" and 6 being "excellent".

After a first analysis of the answers, the survey was changed and adjusted according to the suggestions received, and then validated and applied in the data collection. The selected sample consisted of 53 individuals, which was calculated taking into account the total population considered to have been affected by the floods (68), 95% as confidence level and 5% as accuracy level. The survey was applied to the individuals who are located on the streets close to the Tâmega river in Amarante (Rua 31 de Janeiro and Av. Beira Rio), as well as to some individuals located in areas farther away from the riverside (Largo Conselheiro António Cândido).

Of the 53 individuals considered for the sample, 45 of them answered the survey, which represents 84%. The individuals were mostly males, with an average age of 46.3 years, 63% worked in the high-risk area, more than 50% had high-school education or higher education, 73% had been living for 16 years or more in the area, and 59% had been working in the area for 16 years or more. The survey was hand-delivered.

In a third phase, the data collected was analyzed using the SPSS software (Statistical Package for the Social Sciences), which aimed to obtain statistical validation and correlations.

Finally, in a fourth phase of the study, and based on the results obtained, it was created a Manual of Good Practices (MGP) as a tool for informing and training people for the flood risk in the affected areas. It was also created a group of volunteers to assist in the flood prevention (removal of furniture, products, among others).

3 Results and Discussion

This section discusses the results obtained. As mentioned before, the questionnaire was made among a sample of residents and shopkeepers of Amarante. Based on the results obtained in this section we will later discuss some interventions and measures to counteract the risk of flooding and the damages caused by it. In what follows, we will present the main results obtained.

Of the 45 respondents, 72% were at least once affected by floods. When asked about which events they remember as the most damaging, most answered "March of 2001" and "January of 2016". In the opinion of the majority, those were the floods that caused them greater losses.

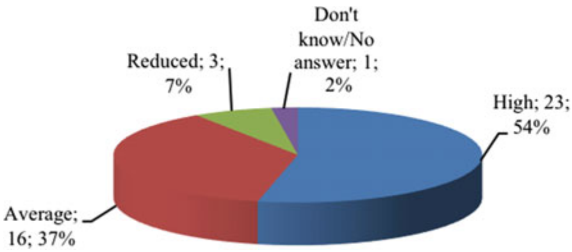
Around 79% of the respondents stated to have suffered damages from the floods, 45% of which reported that the amounts of the damages varied between 500 and 5000 euros, and 21% indicate that they have suffered losses of 5000 up to 15,000 euros, in total.

However, because the study area was considered to be a high-risk area, many respondents believe that most insurance companies do not cover losses arising from this natural disaster, and for this reason, 46% of the population surveyed was not covered by any type of flood insurance. On the other hand, there is a lack of information and communication of the products offered by insurance companies. Based on the data collected we contacted one of the main insurance companies to better examine their policies.

The company presented an insurance proposal, in which this natural phenomenon would be covered. During a meeting with the company, they offered to make their coverage better-known to the shopkeepers, so that anyone interested could subscribe to a contract with them. This initiative was attended by Amarante Civil Protection Services (SMPC), in the person of the Municipal Operational Commander (COM).

Although there are several subsidies and credit lines available, 77% of the respondents did not use any of them. Some examples are: Caixa Geral de Depósitos' credit line and the lines of credit provided by the national government.

Fig. 1 Exposure to flood risk



Among the individuals surveyed, 54% classified "exposure to flood risk" as high, 37% as average and 7% as reduced (see Fig. 1).

When asked about the main causes of the flooding in the riverside area, the residents and shopkeepers mentioned: sudden heavy rains; the existence of litter on the riverbed and on its banks; the lack of measures by the local government; the lack of an upstream dam; the existence of a downstream dam; long-lasting rains; the wildfires; deforestation and lack of land planning.

It was clear that the sample under study is aware that there is a need for more preventive measures. Some of the individuals surveyed had already put in practice measures that helped them minimizing the losses, namely, removal of all products from their stores/houses, placing of furniture and products in higher areas, no use of their basements, improvisation of barriers and water pumping.

More than half of the sample shows confidence in the civil protection policemen. We believe that this level of confidence could be intensified if they were given complete information about the role of the agents and how they work under these circumstances.

According to the respondents, the measures that should be implemented in the city are: a pre-flood warning implemented by the Civil Protection; a permanent monitoring of the water level and enhance the coordination between the Civil Protection Service and the state-owned company EDP—Electricity of Portugal (Torrão Dam); more support should be given to shopkeepers in the removal of their personal belongings and in the acquisition of insurance contracts; no construction of the Fridão dam by the brake that has in its route (the S. Gonçalo bridge); the modification of the Municipal Master Plan (MMP) for the riverside areas; reforestation of riverine areas; the greater control over soil erosion on the river banks and the cleaning of the riverbed and its banks.

The main concerns about future floods are the construction of the Fridão dam; the inability to minimize the damages; the alerts not being given on time; the possible existence of damages to their belongings, businesses and infrastructures; soil degradation; and the modification of natural habitats.

There are two issues that do not hold consensus among respondents. On the one hand, although the majority of the respondents state that the water level in the last decade has been stable, some argue that it is decreasing, and for others, it is increasing. 16% of the respondents think that the water level has been decreasing, 28% think that it has been increasing, 50% think it has been maintained and 6% say "do not know/do not respond", as presented in Fig. 2.

On the other hand, some respondents are not able to distinguish between a flood and the normal rise of water during winter days, and, as regards the average duration of a flood, most refer to hours while others say that it can last days or even weeks.

10% of the sample reported that the average duration of the floods was days, for 78% it was "hours", 3% (one element) answered "one week" and 9% said "do not know/do not respond" (see Fig. 3).

Nevertheless, the population has a sense of belonging to the place where they live or work. 4% answered that they would be willing to move to an area less exposed to flood risk, but the vast majority, 74%, responded that they are not willing to move out, as shown in Fig. 4.

The respondents were divided into three sub-samples: residents; shopkeepers and both residents and shopkeepers. In general, after analyzing the main results, we conclude that the residents and both residents and shopkeepers have a greater perception of the flood risk compared to shopkeepers only. However, the shopkeepers are those who have a greater perception of the measures that the local government implements to mitigate the floods and also a greater concern regarding future floods. This may be due to the fact that residents and the residents and shopkeepers are more familiar with the floods, as well as with the preventive and operational work of the local government's response teams.

Fig. 2 Knowledge of the water level

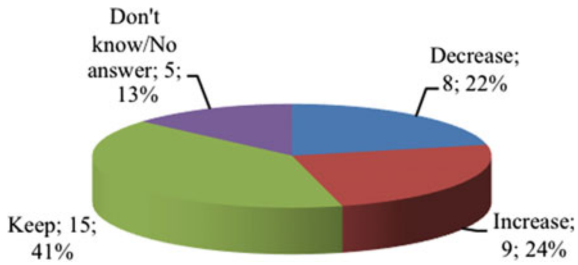
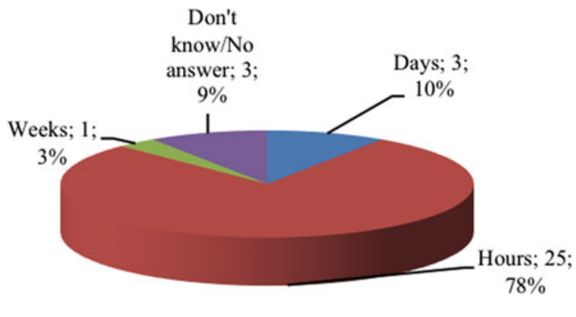


Fig. 3 Average duration of floods



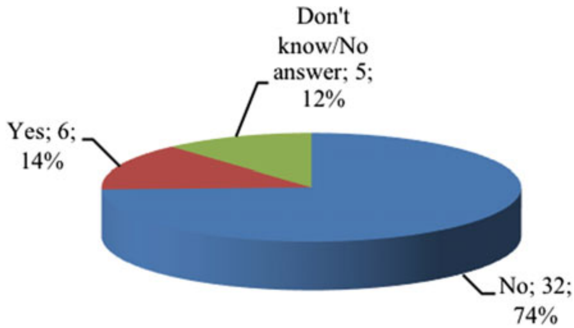


Fig. 4 Move to a less risky area

Although 52% of the respondents answered that they have been assisted in the removal of their belongings from the interior of the store/house, 39% responded that they have not received any assistance. The ones who were assisted, stated that the help was provided by the civil protection, relatives, friends and neighbors.

Finally, and in light of the results obtained, we conclude that in general, the level of awareness for the risk of flooding of the population that is part of the study sample can be considered as high.

4 Follow-Up

Based on the results obtained and with the goal of having the total population living and working in the areas assisted, when these events occur, we created a group of volunteers. First, a meeting was held with the Chief of the Scouts Group 448 of Amarante, where it was proposed the creation of a group of volunteers. These volunteers were asked to be available to help whenever requested by the Municipal Operational Command (MOC). However, the work of this group will always be articulated between the MOC, the Municipal Civil Protection Services and the Chief of the Scouts. The MOC will be responsible for the communication of the flood alerts as well as for providing operationally and logistics information.

A Manual of Good Practices (MGP) was also developed with the aim of spreading awareness, alerting and informing the residents and the shopkeepers about the preventive measures. It includes an explanation the measures that should be adopted before, during and after these events. It also discusses the role of the Volunteer Firefighters and of the Municipal Civil Protection Services, since there are many opinions on which role these different entities should play. The MGP was read and verified by the COM and will serve as an information and prevention tool to be used in the future for the benefit of the population.

5 Conclusions

We conclude that the study sample is aware of the importance of the prevention of the risks of floods, and that the respondents tend to implement their own prevention measures. Most of them are aware of their level of exposure to flood risk and show confidence in the civil protection. This level of confidence can be enhanced if more information is given on the role of the various entities involved.

The fact that 46% of the sample did not define their exposure to risk as “high” may happen for two reasons: they have been working in the area for a short period of time and have not experienced a flood episode yet, or because although they are in the area considered as high-risk, they are located in a level above the level of flooding (over 6.5 m, taking into account the hydrometric scale on the right bank of the river).

Due to the fact that the population has a strong sense of belonging to the place where they live and/or work, they are not willing to move to another location.

We also conclude that a significant share of the necessities reported by the residents and/or shopkeepers of the riverine zone are being filled. One example of the measures that are being implemented is the installation of ultrasonic sensors of water levels. Other measures are expected to be implemented in the future with the help the government of the Municipality of Amarante, and will incorporate the distribution of the MGP that was produced during this study, the beginning of the work of the Group of Volunteers (also created during this study), and the dissemination of information about insurance coverages.

Additional measures we propose are: the cleaning of the rainwater drainage network (gutters, and drainage collectors); reforestation of the areas where there is a greater risk of sediment trapping, and maintenance of the vegetation of the slopes, to help sustain the water.

This work was successful in promoting awareness among the agents involved. They stated that it increased their attentiveness on the importance of alerting the population, informing them about the roles of the civil protection agents, and assisting them during the removal of their belongings from the interior of the houses and/or stores. We believe that this will provide the population better levels of safety and comfort, as well as expose them to less damages.

However, this is a work that requires the constant updating of the prevention measures proposed due to the evolution of the existing natural and social conditions.

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Assessment and Improvement Opportunities for Occupational Health and Safety in the Portuguese Food Processing Industry

Mariana Lourenço, Tânia M. Lima, Pedro D. Gaspar and Fernando Charrua Santos

Abstract The Agrifood Industry is the largest Portuguese Industry, constituted mainly by micro, small and medium-sized enterprises (SMEs). It is noted that more than any other type of organization SMEs have their own specificities that make it particularly appropriate to develop tools to facilitate communication and knowledge sharing for employers and workers. To this extent, identifying critical success factors is the key to increase SMEs productivity. Likewise, Occupational Safety and Health (OSH) in SMEs have their own characteristics, which difficult the prevention strategies implementation and aggravate the problematic of work accidents. This study analyzes a fieldwork in 60 food processing companies in Portugal, related to the dairy, meat processing, bakery and horticultural subsectors, collected in the report "Characterization and Analysis of the Conditions of Safety and Health at Work in Agrifood Enterprises". The analysis of the results allowed to identify that, at the national and regional level, the main failures are concerned with (1) lack of risk assessments regarding occupational noise, lighting, thermal environment and vibrations; (2) safety signaling, the circulation ways are not identified with appropriate safety colors; (3) general lighting, with too many shade areas and finally (4) complementary presence of associated risks to falls at the same level, falling of objects, thermal burns, the use of machines and equipment, fire, mechanical, ergonomic hazards and incorrect body postures. The present study aims to interpret

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the requirements that are in the ideal pattern of work through literature review regarding reality in the fields of OSH, in the Agrifood Industry, with the aim of contributing to the improvement of OSH management and accident prevention of work accidents.

Keywords Agrifood industry · Occupational safety and health · Small and medium-sized enterprises · Dairy · Meat processing · Bakery · Horticultural

1 Introduction

By 2016, micro, small and medium-sized enterprises (SMEs) accounted for 98.8% of all non-financial enterprises in the European Union (EU), equivalent to 22.7 million enterprises [11], employing around half of EU workers, which justifies the need for effective management of Occupational Safety and Health (OSH) in these enterprises, in order to provide the well-being of workers as well as a work environment with harmonized rules, which will enable high-quality products to be obtained, benefiting consumers and businesses, and ensuring their long-term survival [12]. However, statistics show that most of the workers do not have adequate safety and health protection in their workplace, and the percentage of work-related injuries is higher within SME workers [15]. The resources available to SMEs have multiple limitations, which leads companies to opt for cost reduction strategies in order to ensure their economic viability [7]. It is apparent that many workers in these enterprises are more likely to have worse working conditions, less job quality and proportionately greater risks to health, safety and well-being. Taking into account the numbers, the size of the company becomes an organizational risk factor, and the importance of effective means to prevent damage to the health and safety of its workers is evident [3].

Thus, the reasons that identify the poor adherence to OSH management measures in these companies include [16]:

- The weak economic situation of many SMEs and the poor investment they can make in OSH infrastructures;
- The limited level of knowledge, awareness and competence of their owners/managers in relation to OSH, as well as their regulatory requirements;
- Limited ability to manage the business systematically;
- Their attitudes and priorities, given their limited resources and concern for the economic survival of their company, which make SST unimportant.

According to the National Authority for Working Conditions (ACT), the Portuguese Manufacturing Industry corresponds to the sector of activity that presented in the year 2014 the largest number of accidents at work, about 54,000 accidents. With regard to fatal accidents, this sector occupied the second economic activity with more accidents, with a total of 25.

In addition to work-related accidents, several occupational diseases have been linked to work. According to ACT, in 2016, it is also the Manufacturing Industry, which presents the largest number of occupational diseases, about 2,150 records. The most frequent work-related diseases, depending on the risk factor, are the ones caused by physical agents that register the highest number of certified occupational diseases, followed by respiratory system and skin diseases [1].

Faced with these high accident rates, the safety and health issue in the Manufacturing Industry is of particular relevance. Despite all the existing prevention techniques and standards, it is essential that companies have OSH management systems that help to anticipate, assess and control risks by preventing occupational accidents and occupational diseases associated with them [13].

Increasingly, issues related to the health and safety of workers are valued, as the inclusion of OSH preventive measures in companies, can prevent occupational diseases and occupational accidents, considering all productive activities and technological processes involved [10]. It will contribute not only to the reduction of the number of fatalities, but also to the reduction of the number of deaths, incapacities, lost workdays, also for the resulting economic and social costs.

As well as equipment and a working environment appropriately adapted to the needs of the work process, whose maintenance is ensured, improve quality and reduce health and safety risks by increasing productivity [2].

In addition, good practices in the field of health and safety at work are powerful tools to stimulate productivity [8, 14]. Healthy workers can influence company performance: fewer absences from work due to illness, minimizing downtime in the production cycle, higher productivity and quality of work. As well as equipment and a working environment appropriately adapted to the needs of the work process, whose maintenance is ensured, improve quality and reduce health and safety risks by increasing productivity [2]. Therefore, more efficient production processes become more value-added products/services, competitiveness and, consequently, the conquest of markets. Despite the huge global economic recession, many employers are committed to OSH standards [13].

The Agrifood Industry is one of the strategic poles of the Portuguese economy, for the essentiality of the goods it produces and for the value and employment, it generates, and it is in the EU, the largest Industry with a turnover of 1,048 billion euros, of which 51.6% of this figure comes from SMEs [5].

In 2017, SMEs represented 99.9% of the Portuguese business sector and according to statistics, the Agrifood Industry in Portugal represents 20% of the Manufacturing Industry and consists of about 12,000 companies, mostly SMEs, employing around 112,000 workers and representing a turnover of approximately 16,000 million euros [4].

Therefore, since the Agrifood Industry is one of the strategic poles of the Portuguese economy and plays an increasingly important role [9], this study aims to address the essential elements in a perspective of occupational risk prevention in Portuguese SMEs.

2 Materials and Methods

The study analyzes the data collected under the +AGRO project—Organizational Management, Energy Efficiency and Occupational Health and Safety in Agrifood Industry, in particular those contained in the report "Characterization and Analysis of the Conditions of Safety and Health at Work in Agrifood Enterprises" [6], available at: https://maisagro.pt/sst/caracterizacao/.

In the scope of the study, the sample analyzed shows a distribution of 60 companies distributed among the following subsectors (Fig. 1): 15 companies belong to the subsector of meat processing, 12 to the subsector of horticultural products, 16 to the subsector of dairy products and 17 to the subsector of bakery products.

The interpretation of the results was based on direct analysis of the data contained in the report. The data collected have been compiled into tables that showed the values by subsector and region.

In order to systematize the data analysis, it was defined an hierarchy of occupational safety and health conditions, to identify the main risks present in the subsectors, the tables presented a caption with a color code that explains the levels of greater or lesser percentage of companies has the parameters of health and safety at work regulated (Table 1). The percentage refers to the amount of companies analyzed.

Where 0% means the absence of non-conformity in the parameters of occupational safety and health conditions. In other words, all companies find themselves with the regularized parameters, for this motive was assigned the gray color.

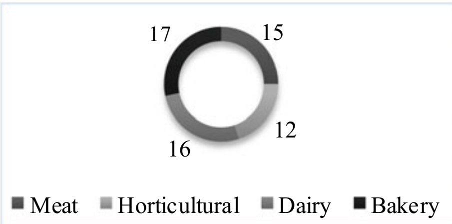

Fig. 1 Distribution of companies by subsector. *Source* Gaspar et al. [6]

Table 1 Legend of colors for tiering OSH conditions

Percentage	Definition	Color
0%	Regularized	
1% ≥ 49%	Acceptable level	
50% ≤ 100%	Not acceptable	

Source Own elaboration

Darker gray means between 1 and 49% of the companies are not within the parameters of occupational safety and health conditions met, is considered an acceptable level because more than half of the enterprises are smoothed.

The black color indicates that between 50 and 100% of the companies are not within the parameters of occupational safety and health conditions, so it is considered as a level not acceptable, as it indicates that more than half of the total companies analyzed are not smoothed.

3 Results and Discussion

In this article, the interpretation of the results was only by subsector were comparatively analyzed, identifying the most eminent risks.

Overall, most of the companies (87%) of the four subsectors have organized occupational health and safety services, although 5% of these companies do not have the services according to the legal requirements. Although most of the companies in these subsectors have OSH services organized, only 60% of the companies carried out risk assessments. As far as occupational noise risk assessment is concerned, only 37% of the companies in the 4 subsectors carried out this type of studies, and according to the project measurements, it was found that in all subsectors there are jobs with noise levels which exceed 87 dB (A), which corresponds to the daily personal exposure limit value. In the case of the thermal environment, only 5% of the companies analyzed in the totality evaluated this parameter. The vibrations assessment is also very neglected by the companies, since only 3% of the companies carried out assessments.

The signalling of circulation routes, which is an important factor to prevent accidents, is not considered an important factor by companies either, since only in 13% of companies in all subsectors there are circulation routes signalled, emphasizing that only 2% of these companies painted the circulation routes of the appropriate colour, that is, yellow or white.

Regarding lighting, in 62% of companies there are shadow areas in the workplace and should be considered one of the main risks by the companies. Low lighting levels can lead to work accidents, increases workers visual fatigue and manufacturing defects, which in this case may give rise to non-compliant food products or with labelling mistakes.

Regarding the complementary risks, the possibility of falls at the same level occurrence, due to the existence of slippery or inadequate floor, was detected in 82% of the companies under study. Another risk that occurs in most companies of the various subsectors analyzed is of the occurrence of thermal burns (77%). With regard to the risks associated with machinery and equipment, 88% of the companies in all subsectors presented this risk, which may entail risks to the physical integrity of workers. The risk of entrapment, shocks with objects, cuts or perforations was observed in 92% of companies. The risk of fall of objects that can hit and injure workers was identified in 79% of companies. Last but not least, another risk found

Fig. 2 Most eminent risks in the four subsectors analyzed. *Source* Own elaboration

Risk assessments
Security signalling
Illumination
Complementary risks

in most of the companies studied is due to inadequate and poorly ergonomic postures. These situations were observed in 93% of companies. Focusing on the four subsectors studied, it is concluded that the subsector of horticultural products is the most problematic subsector with high percentages in most of the analyzed parameters. Besides the risks common to all other subsectors of activities, it presents some others that require special attention, for example, in only 58% of companies there are OSH services organized. In relation to the regions covered by the project, it is complex and difficult to identify the most affected region of intervention, even in each subsector.

Carrying out risk assessments, tests and measurements procedures during the activities to characterize and analyze the OSH conditions it is still possible through a great progression margin to guarantee the workers' safety and health. The most eminent risks in the four subsectors (Fig. 2) analyzed were firstly the lack of risk assessments per workstation, specifically, noise level, thermal environment and vibrations. Secondly, the security signalling, since most of the circulation routes were not signalized and in the cases that they were in majority of them the colour was not appropriate. Thirdly the illumination with the existence of areas with shadows. Finally, in relation to the existence of complementary risks, such as the ones associated with falls, thermal burns, machinery and equipment, mechanical hazards, falling objects and ergonomic risks and incorrect body postures. It is also concluded that, among the four subsectors studied, the subsector of horticultural products is the most problematic subsector, since it has presented high percentages in most of the parameters analyzed, and besides the risks common to all other subsectors of activities, have presented some other ones that require their due attention.

4 Conclusion

The conclusions of this study indicate that risks may be better managed in this group of companies, where good OSH conditions are associated with business success. The size of an enterprise limits its resources, its financial capacity and its technical means to analyze risks and to adopt preventive practices, however, prevention is essential for a healthy workplace in every company, regardless its category or size. Then, it is a priority to carry out periodic risks assessments either to identify hazards, to implement measures to eliminate or reduce them, in order to protect the workers properly.

A well-implemented OSH service guarantees the reduction of accidents, occupational diseases, absenteeism and consequently improves the quality of work, resulting in an increase in productivity and greater competitiveness of the company. But however important an OSH program may be, and the better the tools it provides for the diagnosis and resolution of work risks, if there is no willingness, participation and commitment of all involved in these actions, especially employers and workers, the results will be limited, both qualitatively and quantitatively. Work in Industry requires concentration and a sense of responsibility. The worker must possess the technical, physical and psychological skills necessary to comply with safety standards and adopt a preventive approach in order to avoid work-related accidents and future work-related illnesses. These capabilities should be part of the measures proposed in the information and training programs for OSH promotion, sensitizing workers to the risks they are exposed in order to increase their awareness of them.

One of the key elements of success is how stakeholders, from employers and workers to government agencies, approach this thematic. Creating a new policy framework will help SMEs to grow, reducing the bureaucratic process to avoid the discouragement associated with the predictability of rising costs; facilitating access to finance; improving access to third country markets; supporting the acquisition of skills and encouraging investment in innovation. In order to protect workers, where health and safety interventions can affect productivity and profits, these can be some of the ways to level the field of professional action to ensure that all businesses operate in a similar and safe way for workers and consumers.

It is also concluded that the report analyzed presents results whose domain can lead to some misunderstandings due to some lack of clarity in the criteria used in the evaluation. The opportunity for a more detailed investigation, provided by greater and equal sample of companies in each subsector, as well as the measurements in all workstations, reflect a deeper comparative analysis, with stricter quantitative data on the national reality. Nevertheless, go beyond limited perspectives by the authors of the report, would be advantageous for instance to include psychosocial risks evaluation.

Finally, given the importance of this thematic, there is still a long way to go in the field of research, not only in health and safety at work in Agrifood companies, but also in the SMEs.

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Towards a Private Health Judicialization: A Court Processes Analysis in Brazil

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Abstract This study aimed to evaluate the degree of social responsibility of companies operating in the supplementary health market in the state of São Paulo. Specifically, the analysis falls on two of the fundamental principles of corporate social responsibility: ethical behavior; and respect for the rule of law (ISO 26000). For this, an analysis of the judgments related to supplementary medical care recorded on the website of the Court of Justice of the State of São Paulo (TJSP) for the years 2016 to 2018 was carried out. The results show that the supplementary health care providers appeal to postponing their obligations, even if unfavorable court decisions are expected. The authors conclude that the state should provide incentives, positive or negative, to discourage supplemental health judicialization and thus contribute to a greater engagement with corporate social responsibility.

Keywords Private health system · Judicialization · Stent · Corporate social responsibility

1 Introduction

In recent years, awareness of the social responsibility of organizations has increased for a number of reasons: increased mobility, accessibility and communicability in globalization allow a comparison of practices adopted by organizations in different places; the global nature of some environmental and health issues; recognition of global responsibility for combating poverty; the increasing financial and economic interdependence; and the increasing geographic dispersion of value chains. These and other factors indicate that issues relevant to an organization may have a far greater reach than those geographically restricted to its field of action and constitute the context of social responsibility, helping organizations demonstrate their social responsibility. (ISO 26000) [1].

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ISO 26000 [1] defines social responsibility as an organization's responsibility for the impacts of its decisions and activities on society and the environment through ethical and transparent behavior that contributes to sustainable development, including the health and well-being of the organization.

This standard lists seven principles of social responsibility: Accountability; Transparency; Ethical behavior; Respect for the interests of interested parties; Respect for the rule of law; Respect for international norms of behavior; and, Respect for human rights. Despite the importance of all these principles, we will focus our analysis on two principles: Ethical Behavior, which implies that the behavior of an organization must be based on the values of honesty, justice and integrity; and the principle of Respect for the Rule of Law, which assumes compliance with legal requirements in all jurisdictions in which it operates, even if those laws and regulations are not adequately supervised.

According to the Observatory for the Judicialization of Supplementary Health (2018), the volume of decisions on the subject has increased by 329% (three hundred and twenty-nine percent) in 7 (seven) years. In addition, according to Scheffer [6] and to a survey conducted by the National Justice Council (CNJ) in 2016 at least 1,346,931 (one million, three hundred and forty-six thousand, nine hundred and thirty-one) health-related cases were processed in the Judiciary. The term judicialization used here comes from the concept coined by Tate and Vallinder [7] to define the influence of the Judiciary in political and social institutions. On the other hand, health supplementing medical care is defined as plans and insurance offered by private companies.

The health insurance plans are responsible for the medical-hospital care of approximately 40% of the population of São Paulo, Brazil. Contracts for health services are contracts of adhesion, which means that no changes are allowed in the contractual clauses and the consumer must accept or refuse the entire contract.

Health insurance contracts, however, are *sui generis* insofar as they deal with an object that constitutes an unavailable legal asset (life), so that it is not allowed that the consumer makes concessions that may in the future involve lack of coverage in relation to something that affects their health, under penalty of contract's social function violation, which is the general principle of the Brazilian Civil Legal System. Health plans are operated as a rule by profit-making companies and must follow detailed regulations to remain authorized to operate in Brazil.

The goal of this study is to evaluate, from the perspective of ethics and corporate social responsibility, the behavior of health plan operators operating in São Paulo. Using public data collected on the Court of Justice of the State of São Paulo (TJSP) website, an analysis of the performance of insurers was carried out in cases whose unfavorable judicial outcome was already expected, given the content of previous precedents.

2 Theory and Jurisprudence

The Supreme Court of Brazil (STF) publishes a pacific and uniform consensus or legal understanding of the court about a subject—the Precedent. Important to remember that only the STF publishes the "Binding Precedent", through which obliges all other courts and judges of the country abide by their decisions.

The Precedents issued by the TJSP do not have the binding effect such as those issued by STF, but are used as guideline and jurisprudential standardization clarifying the rules for all interested parties and increasing the predictability of the legal system. The main precedents of TJSP are aligned and classified into 7(seven) groups according to their core interests: Prosthesis and Orthesis, Stent, Cardiac Pacemaker, Surgical materials, Indemnification (material or moral), Medicine/ specific examination and Medical Specialist.

The precedents listed on Table 1 represents the peaceful jurisprudential understanding on necessary materials for the surgical act, use of stents, prostheses and orthoses, but, every day new denials of costing by health plans and insurers occur.

Due to this refusal of coverage by the companies, the insured are impelled to sue the companies, for breach of contract. A breach of contract occurs when one of the parties fails to honor his or her responsibilities under a contract.

As a rule, in addition to the request for coverage, these lawsuits include compensation for moral damages due to the frustration of expectations and the aggravation of the psychic suffering and the anguish that the negative coverage brings.

This performance of health insurance companies and operators in the refusal of coverage understood as compulsory by the Judiciary not only affects the expectations of the consumers who have contracted the insurance, but also the basic principles of corporate ethics and corporate social responsibility that the main companies identified in the processes they claim to have, according to information made available on their websites.

This is because corporate social responsibility presupposes the construction and maintenance of social rights both internally in the corporation and externally in the environment in which the company is inserted. Therefore, companies must not only

Table 1 TJSP's precedent related to the appeals core interests

Legal reference	Content
Precedent 93	The stent implantation is an act inherent to cardiac surgery/vascular, being abusive the negative of its coverage, even though the contract prior to the Law 9.656/98
Precedent 95	If there is an express medical indication, health plans can not deny coverage cost or drugs supply associated with chemotherapy treatment
Precedent 96	If there is a medical indication of exams associated with the illness covered by the contract, the health plans can not deny the procedure coverage
Precedent 102	If there is a medical indication, it is abusive the refusal to cover treatment costs on the grounds of their experimental nature or because it is not provided for in the list of procedures of the National Health Agency (ANS)

act correctly, but also measure the impact of their business decisions, especially on stakeholders who may be directly affected by them.

It's important to notice that in the opinion of Carroll [2], law is seen as minimal ethical behavior and the goal is to companies operate well above what the law mandates, performing in a manner consistent with expectations of government and citizens, which did not occur on the founded cases.

According to Davis [4], Carroll [3, p. 275], social responsibility starts at the place where the law ends, that is, a company is not acting in a socially responsible way when it only meets the minimum legal requirements for action, given that such conduct is expected, corporate social responsibility being the step beyond. The definition of stakeholder used in this work is given by Johnson et al. [5], who understand that this concept is linked to individuals or groups that depend on the business organization to achieve their personal goals at the same time that the business organization depends on the success of these individuals or groups to last in the economic competition. To frustrate the legitimate expectations of its policyholders, denying procedures that will later be authorized by the Judiciary and its Courts is an action that does not comply with the basic concepts of corporate social responsibility, which imposes a reflection on the behavior of the companies that act in the provision of private health care, since the results found by this study confirm the judicial reversal of the denied service.

3 Methodology

This is an exploratory study based on secondary data available at the Court of Justice of the State of São Paulo website (www.tjsp.jus.br), considered the largest court in the world according to Revista Consultor Jurídico [8].

São Paulo was chosen because it is the Brazilian state with the highest rate of supplementary health coverage, with about 45% of its population linked to a health insurance plan or insurance.[1]

According to the Revista Consultor Jurídico [8], 500,000 new appeals to the TJSP come to the TJSP in addition to the accumulated amount of previous years, resulting in more than 1 million appeals being processed by the Court. The selection of the TJSP's judgments used in this study set a time horizon of 3 years (2016 to 2018) of appeals analysis and regarding to 2018, was taken into account those judged until November 14, the last date with data made available by the Court before the closure of the research.

Second, the authors analyzed the judgments that decided the merits of the issue, giving an outcome to the case, such as mandatory review and appeal.

[1]BRASIL. Ministério da Saúde. ANS. Caderno de Informação da Saúde Suplementar: Beneficiários, Operadoras e Planos, set. 2014. Rio de Janeiro: ANS, 2014.

The keywords used in the Brazilian Court judgments research were: Precedent 93 (Súmula 93 in Portuguese language) and Stent. It is important to note that the consultation of jurisprudence occurred in the Service Portal (E-SAJ), a public database available on the Internet.

The total of appeals analyzed in this study was 220 (two hundred and twenty), being 82 (eighty two) for 2016, 78 (seventy eight) for 2017 and for 60 (sixty) for 2018. These groups were defined based on the main demand of each process, and there may be intersection between the groups, such as a process for stent placement and a claim for moral damages.

The data were analyzed using the Software Package for Social Sciences (SPSS for Windows, version 17.00), being submitted to the descriptive analysis, obtaining absolute and relative frequency.

4 Results

According to the research promoted by Scheffer [6], among the processes judged on second instance of TJSP (12,078 in total), the majority is related to the exclusion of roofs or negative of visits (40% of the decisions). The second reason (24% of the decisions) refers to the recovery of monthly fees, accident claims or increases in collective agreements.

This work focused on the denial of care that led to lawsuits and consequent appeals by health plans. The analysis of the data (Table 2) shows that despite the explicit normative content contained in the precedents of the courts, the plans still deny the placement of prostheses, orthoses or stents.

There is also a concentration of judicial appeals between the operators, so that 4 operators hold 63.19% of the cases: Unimed (19.55%),[2] Bradesco Saúde (16.82%), SulAmérica Companhia de Seguros (15%) and Amil Assistência Médica (11.82%) (see Fig. 1). This partly reflects the market concentration, since these same operators hold about 50% of the total beneficiaries (ANS 2018). However, calculating the ratio between market share and the appeals percentage per operator, this study find that Bradesco Saúde and SulAmérica Seguros have a odds ratio of 2.58 and 4.11, respectively, indicating that these operators have high odds to appeal in court in comparison to others health insurance operators (Table 3).[3]

The analysis of the judgments appeals during the years 2016 to 2018 identified the presence of three courts counties with the highest volume of sentences, namely São Paulo, Santo André and Osasco.

[2]All the decentralized plans of the UNIMED were contemplated.

[3]The hypothesis is that the distribution of lawsuits is independent of health insurance company.

Table 2 Classification of TJSP's judicial appeals—2016 to 2018

	2016	2017	2018	Total Qty	Total Qty (%)
Prosthesis and orthesis	34	39	16	89	40.45
Stent	31	25	25	81	36.82
Cardiac pacemaker	4	5	5	14	6.36
Surgical materials	5	1	7	13	5.91
Indemnification (material or moral)	4	5	1	10	4.55
Medicine/specific examination	2	3	5	10	4.55
Medical specialist	2	0	1	3	1.36

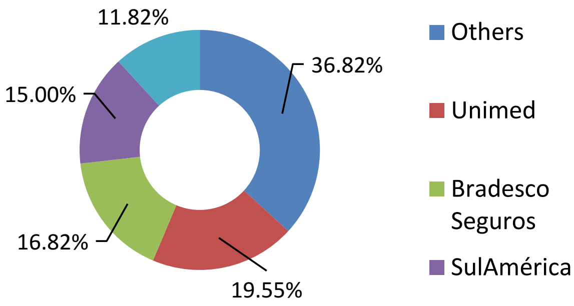

Fig. 1 Distribution (%) of judicial appeals between the operators

Table 3 Market share versus judicial appeals and odds ratio, 2018

Insurance company	Market share (%)	Appeals (%)	Odds ratio
AMIL	11.00	6.67	0.58
BRADESCO	8.29	18.33	2.48
UNIMED	25.11	20.00	0.75
SULAMERICA	6.30	21.67	4.11
Others	49.30	33.33	0.51
Total	100	100	

Source TJSP and ANS (2018)

The results of this research are in line with the work developed by the Scheffer [6], which analyzed the 12,078 actions against health plans and identified the main regions in the volume of decisions, 6,476 decisions (53.6%) are from the São Paulo (capital), São Bernardo (504 decisions), Santo André (412), Campinas (315), Santos (271) and Osasco (249).

5 Conclusion

This work was an exploratory study and points to an incompatibility between corporate social responsibility that the main companies condemned by the Brazilian Judiciary sphere for not complying with the legal coverage envisaged claim to have in their electronic websites and their actions in the judicial processes, that even condemned in first instance, appeal even knowing that there is a peaceful position of the Courts that the conduct adopted by them is not correct under the legal prism.

Such action by the companies allows us to infer that there is an attempt to postpone the costs of health treatment of its insured persons through the judicial system, so that payment of the treatment will only occur at the end of the process, which will take on average 54 (fifty four) months, according to data from the National Council of Justice, for the year 2016.

This postponement of the payment timing often does not generate any kind of benefit for the insured, since the moral indemnity is not unanimous, being granted in some cases, which increases the incentive for delaying the payment and the use of the judicial system as means to save time to make the payment.

Obviously, the adoption of this form of conduct not only hurts corporate social responsibility, but also obscures the legal duty of transparency of these companies, since they will knowingly deny the coverage of prostheses, heart valves or stents to the detriment of their insured, contrary to the Courts of Justice precedents and guidance.

As a solution, the authors of this study consider it necessary to include a pre-fixed amount of indemnity to the insured in cases of refusal to grant coverage that contradicts the precedents agreement and whose result has already been informed the litigant companies and, in the case of a pre-existing court decision, its denial of coverage in the next cases of similar nature in the future, should be sanctioned not only with the reversal of the negative, but also with indemnity.

Thus, it is possible to create an incentive for companies to stop using the judicial system as a means of postponing payment, which will reduce the suffering of the insured and the cost of the judicial system, causing fewer processes, as well as forcing companies to calculate the claims ratio better, business overall cost, better products and services offerings, and finally, a real development of corporate social responsibility, which nowadays appears to be merely figurative.

Finally, it is the responsibility of organizations to guide their behavior in norms, guidelines or rules of conduct that are in conformity with the universally accepted principles of ethical and moral conduct and that guide the company in the construction of a more just and egalitarian society.

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Sustainable Business Strategies: What You Think Is What You Do?

Eduarda Pereira, Isabel Loureiro, Paulo Ribeiro, Susana Costa, Nélson Costa and Pedro M. Arezes

Abstract Considering the perspective of the triple bottom line (TBL) concept, cities create conditions that enhance the economic, social and environmental aspects. Among the determinants that affect the business, we can include the concept of corporate sustainability resulting from the concept of globally oriented sustainable development. Sustainable development is the issue of the moment in the business world and how companies should be guided to meet stakeholders demands and assess social, economic and environmental impacts. Health and Safety at Work and sustainability can't be dissociated, with a common focus on the idea of meeting human needs, as well as the systemic perspective of the interdependence and interrelationship between human activities and all the surrounding systems. The aim of this study is to develop and apply a systematic data collection instrument to evaluate the perception and actions developed by the companies of Guimarães Marca in relation to sustainability and sustainable development. The data allow us to infer that the perception and behavior of organizations regarding sustainability and its benefits are positive.

Keywords Sustainability · Corporate sustainability · Performance
Human factors · Occupational

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1 Introduction

In the mid of the 90s local authorities were probably the most active layers attempting to implement sustainable development. According to Dyllick and Hockerts [1], the focus has changed and the corporate sector has now become the main actor.

Among the determinants that affect the business, we can include the concept of corporate sustainability resulting from the concept of globally oriented sustainable development. Initially, the macroeconomic approach focused on introducing and resolving the global problems of humanity with an emphasis on natural resource management. However, the present time requires involvement of the corporate sector in this complex issue [2].

Corporate sustainability is based on TBL [2]. Thus, in line with the definition of the World Commission on Environment and Development, corporate sustainability means:

> … to meet the needs of direct and indirect stakeholders … without compromising the needs of future stakeholders. [1]

The massive transformation of the business landscape in recent years (the constant changes in the market, the accelerated pace of innovation) forces the flexibility and availability of companies to meet the increasingly demanding requirements of the market by it self, compliance with the regulations aimed at sustainability, and yet to remain competitive in a global market [3]. Several concepts have been developed within the corporate environment, such as social responsibility, social performance and environmental management, in the hope of providing an approach that supports long-term business sustainability [4]. From its integration, corporate sustainability has become more than a simple concept, in fact it has become a determining factor for the success of companies.

According to Savitz [5], a sustainable company is one that generates profit for shareholders and simultaneously protects the environment and improves the quality of life of the people with whom it interacts. Meeting the human needs should be the main reason for companies. On the other hand, they create needs and thus influence consumption and lifestyle. From the economic point of view, it should meet the needs of the current stakeholders, with a view to continuity. Corporations that adopt short-term return policies and related strategies are not considered sustainable [6]. Dyllick and Hockerts [1] establish three key elements in the concept of corporate sustainability:

- Integration of economic, ecological and social aspects into a TBL: the financial part should not be the only prerequisite. Environmental and social gains should also be part of profit, as well as their impacts and interdependencies.
- Integration of "long-term" and "short-term" concepts: corporate sustainability requires a long-term business plan that addresses the needs of stakeholders.
- Consumption of income rather than capital: the requirement to maintain capital base is a common denominator in the business world and it is widely accepted

as a precondition for successful and responsible management. However, to achieve long-term sustainability, companies will have to manage not only economic capital, but also their environmental capital, human capital and social capital.

Sustainable development is the issue of the moment in the business world and dictate how companies should be guided to meet stakeholder demands and assess social, economic and environmental impacts [7]. Business sustainability can be called a philosophy and depends on the economic conditions of the company, the complex business conditions and the willingness of company representatives to act in accordance with these principles. This decision requires a transformation in the overall strategy and in all its components [2], considering the entire business chain [4]. A company that adopts the principles of sustainability in its organization should carefully evaluate its mission, its vision and its values [8].

Kondoh et al. [9] mention the importance of considering the concept of externality in a sustainable business model. The concept of externality is traditionally related to the cost/benefit of processes, namely in relation with partners, corporate social responsibility strategy, ecological footprint, regulations, legislation, among others, encouraging the reduction of the cost of products, a circular economy and the creation of social value.

Therefore business TBL is part of a co-evolution context, where micro- and macro-systems cooperate and organize themselves for the same purpose [1, 10].

In a given business model companies configure a set of activities and elements, in a logic of profit and competitiveness [9]. Economic sustainability encompasses the general aspects of an organization that must be respected (alongside environmental and social aspects) to remain on the market for a long time [10].

The economic dimension of corporate sustainability is taken as generic, an aggregate view of the right things and provides a good socio-economic result of the activity. Positive financial results, beneficial impacts on society and the environment are associated with the effectiveness of the company. The environmental dimension is directly related to the business conscience about the impact of its activity on the environment and arises in the nexus of the relationship between environmental sustainability management and social sustainability [1]. The social dimension of companies reflects everything that happens within the company and that is projected abroad and vice versa and similar to eco-efficiency, but much less exploited, the concept of socio-efficiency describes the relationship between the added value of an enterprise and its social impact [10, 11]. The social dimension essentially promotes equity and aims to be a guarantor of general well-being [11].

Organizations that adopt the TBL concept and practices tend to be more conscientious and clear about their own mission [12]. As a result the great challenge is to form sustainable companies, because only in this context is the observance of the interdependence of various elements of society maintained with the goal of strengthening the relationship network that keeps them integrated [4, 13].

Workers' resistance has been identified as an obstacle to the implementation of sustainable behaviors, because they are seen as extra work in their daily lives, mainly because of fear and lack of information. The training of workers is imperative, not only in a logic of demystification, but also with the aim of projecting the benefits of implementing sustainable practices [14]. A whole culture will be changed and it is necessary to understand that developing a consistent sustainable strategy implies the knowledge of guidelines that allow to obtain a holistic vision of sustainability and informed decision making [15], thus creating companies that catalyze the desired social, environmental and economic transformation.

Thus, the objective of this study is to develop and apply a systematic data collection instrument to evaluate the perception and actions developed by companies in relation to sustainability and sustainable development.

Guimarães is located in the north of Portugal, being the fifth most industrialized region of the European Union [16]. The Municipality of Guimarães is making a bet on the economic investment in order to attract and consolidate the local business fabric.

According to the data released [16], Guimarães is part of the more industrialized areas of the North, "where the robustness and the business environment create better opportunities for its residents", being the second city that is not a district capital to occupy a place in the national ranking. With about 3000 companies, the municipality of Guimarães creates the Guimarães Marca project, which has 54 associated companies.

Industry 4.0 is a term that describes the impending changes in the industrial setting, particularly in the production and manufacturing at a global level. At the root of the revolution of an industry 4.0, products, machines and people are increasingly networked through digital platforms that provide real-time information [17]. From here, you access a new productive reality: everything will be connected so that the best decisions of production, cost and security are taken in real time. It is in this context of competitiveness, quality and sustainability that Guimarães Marca intends to associate itself with the industries of the municipality, promoting opportunities, intensifying the attractiveness of the municipality in order to engage new national and foreign investments, and stimulating the existing entrepreneurship, thus creating a mark of excellence.

2 Methods

This work was carried out through scoping review of the corporate sustainability concept integrating the incipient concept of performance in the context of human factors. According to Colquhoun [18], this methodology is "a form of knowledge synthesis that addresses an exploratory research question aimed at mapping key concepts, types of evidence, and gaps in research related to a defined area or field by systematically searching, selecting, and synthesizing existing knowledge". It is a very popular methodology for systematizing scientific knowledge, with a steep growing expression among the scientific community the last 4–5 years.

This case study was conducted to the companies of the Guimarães Marca to evaluate the perception and actions developed by companies. We have chosen the Guimarães Marca case because there is a lack of empirical research on this field. To accomplish this task, a questionnaire was developed elsewhere for this study [19]. First, an expert panel method was employed to choose the questionnaire. Then, it was submitted to a pre-test in 10 companies. The questions were structured in order to evaluate perceptions on the one hand, and actions on the other. In total we received 27 surveys duly responded (the response rate was 54%).

3 Results and Discussion

The sample comprises 27 companies. When analyzing the size of the company, 81% (22) of the companies employ up to 100 employees, and 85% (23) have a turnover of more than one million euros. The textile industry represents the main activity sector of the companies studied.

The perception of the companies in relation to the benefit of the use of sustainable practices was analyzed (Fig. 1).

Most companies consider the sustainable development of the company and the implementation of measures with this approach very important. It is noticed that some companies consider that they do/implement more than necessary, and others think they perform enough. It is difficult to understand the standard used in the answers, since we analyze perceptions that, by definition, do not reflect reality because they belong to the subjective domain of each individual, in this concrete case, in relation to what each company considers sustainability.

The perception is influenced, among others, by the personality of the individual, by interests, motivations and expectations and often the statistics contradict our perception and the obtained results are considered biased. Therefore, one will

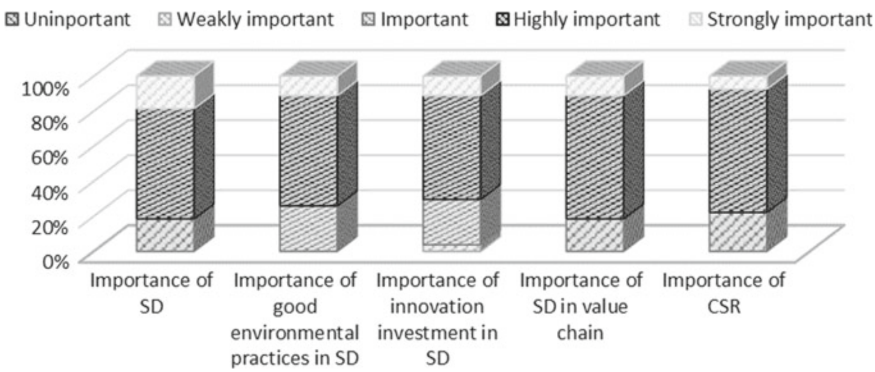

Fig. 1 Corporate sustainability's perceptions (SD: Sustainable development; CSR: Corporate social responsibility)

Table 1 Corporate sustainability's perceptions versus actions

	Actions				
Perceptions	Investment in sustainable practices	Investment in certifications/ lean practices	Investment in good environmental practices	Investment in innovation	Investment in Occupational Health and Safety (OHS)
Importance of SD	$p > 0.05$	$p > 0.05$	$p > 0.05$	$p > 0.05$	$p > 0.05$
Importance of CSR	$p > 0.05$	$p > 0.05$	$p > 0.05$	$p > 0.05$	$p > 0.05$
Importance of innovation investment in SD	$p > 0.05$	$p > 0.05$	$p > 0.05$	$p > 0.05$	$p > 0.05$
Importance of good environmental practices in SD	$p > 0.05$	$p > 0.05$	$p > 0.05$	$p > 0.05$	$p > 0.05$
Importance of SD in the value chain	$p > 0.05$	$p > 0.05$	$p > 0.05$	$p > 0.05$	$p > 0.05$

discuss in order to compare the perception and the measures taken, and to obtain conclusions regarding the coherence between what you think and what you do.

The data were transformed in order to obtain a 2×2 contingency table for the application of Fisher's test. It is observed that there is no dependency between the hypotheses (Table 1).

Nevertheless, it was seen that the perception and attitudes of local corporations concerning sustainable activities is considerably positive (96%).

One of the conclusions of this study with respect to environmental issues is that even though 25.9% of the respondents do not consider important environmental issues, 96% of the respondents invest in good environmental practices. This suggests the integration of industry 4.0 within the sustainable development goals, and the extension of companies that already have begun to recognize the benefits and competitive advantage associated with proactive environmental activities [20].

OHS is a multidimensional challenge and is a critical point for operational excellence [21]. When questioned about the importance of CSR and investment in OSH, 96% of companies responded to investing in OSH. In fact, simple improvements can represent an increase in competitiveness and profitability for the company, creating a more competent, more flexible and healthier workforce, which companies recognize [22], even though only 74% consider CSR important. It's seems reasonable to attribute this fact to scope of action of each one.

Most of the companies invest in management systems (96%). The data obtained allowed to observe that for most companies, the certification in quality and the use of lean practices is important and implemented, but the certification in safety was mentioned only by one company. This suggests a strong association of lean practices with sustainability.

It is concluded that there is an economic relationship within corporations between human and environmental capital, advocated in the concept of the TBL sustainability.

4 Conclusions

The survival of companies is the main reason for planning activities that aim to increase profit, reduce costs, generate new opportunities and thus position themselves in the market. The whole strategy requires adaptation to the new paradigms, namely to sustainability issues, which embody social and environmental responsibility. This is the major challenge facing companies, in times of complex resolution of equations. A sustainable company is a system that generates profit and, simultaneously, protects the environment and improves the quality of life of the people with whom it interacts. In the interface of sustainability and human factors when we talk about the maintenance of human capital, we refer to worker health and safety, social dialogue and employee representation.

The object of study were companies of the Guimarães Marca, with a response rate of 54%. One of the main limitations of this study was the sample size.

The results suggest the positive economic relationship with human and environmental capital, advocated in the concept of the TBL sustainability. The data allow us to infer that the perception and behavior of some companies in relation to sustainability and its benefits are globally interconnected. Some companies are highly committed to sustainability issues, in others the data suggests a link between perception and commitment to sustainable activities. Others, however, have proved to be reactive, that is, weakly committed to sustainability actions.

For future work, it would be pertinent to apply benchmarking strategies in order to know the reality of so many other existing companies and to understand the best strategy to obtain comparability of intra- and inter-company indicators. New discussions should be held on the knowledge and application of sustainability management and certification systems, in order to promote a safer, innovative and sustainable environment, aligned with industry 4.0 and society 5.0.

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The Importance of Emergency Response Training: A Case Study

Ana Sofia Pinheiro, Rui Gouveia, Ângelo Jesus, Joana Santos and João S. Baptista

Abstract The success of the Emergency Plan depends on the ability of its occupants to respond. For this reason, it is fundamental to develop an appropriate training strategy for each organization. This pilot study aimed to understand the influence of specific training program on the emergency response. This study included a total of twenty-two workers of a company. The workers were divided into three emergency response teams with four elements and one another group with ten elements. The emergency response team had specific training actions with theoretical and practical contents. Finally, all workers participated in an activity called emergency scenarios, where a moment of brainstorming was provided for the solve each scenario. The classifications obtained in different assessments moments (M1: after training and M2: after three weeks of training) revealed that knowledge had been acquired by participants. Additionally, it was verified that teams, with specific training, presented better results in their specific scenario. The emergency response training may have better results if it enhances teamwork and the involvement of all stakeholders.

Keywords Emergency response team · Evacuation · Training · Education

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1 Introduction

Nowadays, the news related to emergency scenarios in buildings and the difficulties in occupant's evacuation is, unfortunately, still considerable. Despite all the technological and scientific advances, the increasing availability of information and legislative regulations, there is still gaps in this system. Emergency and fire safety in buildings have a legal basis. However, this theme also contemplates a moral obligation, since its non-fulfillment could result in the loss of lives and property. When accidents occur in this context, their severity has the potential to be catastrophic, with irreparable damage, which could lead to the degradation of families and bankruptcy of companies. An organization may comply with the legal requirements; however, if the workers are not sensitive to the issue, no plan can be effectively implemented to be successful. The fulfillment of Portuguese law includes the education and training of emergency response team, responsible for intervening at various levels in an emergency scenario. Thus, it is vital to prepare individuals with skills that enable them to act according to the role in the organization.

1.1 Emergency Response and Evacuation

Evacuation can be defined as the process of leaving the buildings and their involvement in an emergency case, safeguarding human lives. In this process, human and organizational factors influence, according to Norazahar et al. [1], failures in alarm activation, intervening reaction capacity, command and control deficiencies, and communication problems. Shields and Boyce [2] mentioned that one of the leading causes for deaths in an emergency scenario is not the distances to the emergency exit, but the delay in communications to the occupants of the situation. These authors also referred to factors such as alertness, mobility, social affiliation, role and responsibility, as well as familiarity with the building, have a significant influence on the behavior and movement of the occupants. When a fire starts, occupants do not identify themselves as being at risk, resulting in late adoptions and evacuation. Thus, risk perception plays a fundamental role in risk management and support of prevention strategies, since the behavior of individuals will depend on the interpretation of the situation, and therefore on their ability to observe [3]. Tancogne-Dejean and Laclémence [4] identified as overconfidence, excessive control, fatalism, affectation, social withdrawal, and non-vigilance due to the existence of technologies and regulations as factors that limit the risk perception. Although, overconfidence can be detrimental to risk perception and, consequently, to evacuation, this factor can reduce stress and negative emotions in emergencies.

Another factor that is influencing the emergency response is situational awareness. Li et al. [5] studied this factor in a sample of first intervention workers to understand the privileged information in case of emergency. During the emergency and considering the order and frequency of use of the information, and also the importance given to it, the following information was considered as main information: the location, size, and duration of the fire, the presence and location of the occupants, and the location and conditions of smoking. Considering the importance of workers' education/training about different types of emergencies in the companies' context, this study aimed to understand the influence of a specific education/training program on the emergency response, using learning strategies that reinforce the teamwork and the involvement of the participants.

2 Materials and Methods

2.1 Sample

This study was conducted in a company that commercializes equipment's, machines and chemical products for the graphic industry. Additionally, the company developed repair and paint activities. The Emergency Plan of the company defined the emergency response teams. Twenty-two workers (17 males and 5 females) were involved in different training actions. On average, participants had 45.68 (±9.23) years and 15.73 (±11.50) years of work experience. All participants signed an informed consent.

2.2 Training Actions

Workers had four different education/training sessions. In the first training action called "General Training: workplace emergencies and evacuations" (GTWEE), all participants (n = 22) were included. The remaining training sessions were applied to emergency response team, defined in the Emergency Plan and called "Training for Firefighting Team" (TFT) (n = 4), "Training for Alarm, Alert and Evacuation Team" (TAET) (n = 4), and "Training for First Aid Team" (TFAT) (n = 4). The theoretical and practical contents are present in Table 1.

All training sessions had 60 min to theoretical contents and approximately 30–40 min for practical exercises. The contents explore the individual roles and responsibilities, emergency-response policy and procedures associated with the action of emergency response team on the company. The general contents were evaluated, using a specific test with multiple choice questions and were applied in

Table 1 Description of training actions

Training action	Theoretical contents	Practical contents
General training: workplace emergencies and evacuations (GTWEE)	Topic 1: emergency Topic 2: autoprotective measures Topic 3: safety equipment's Topic 4: safety signs Topic 5: emergency plants Topic 6: emergency response team	Identify fire extinguishers, fire hydrants, fire doors, and emergency exits
Training for firefighting team (TFT)	Topic 1: fire characteristics Topic 2: fire causes and effects Topic 3: type of fires and suitable extinguishing media Topic 4: first Intervention equipment's Topic 5: safety in the use of Fire extinguishers	Use of a fire extinguisher
Training for alarm, Alert and evacuation team (TAAET)	Topic 1: alarm and alert Topic 2: energy, gas and water closing Topic 3: evacuation Topic 4: evacuation team Topic 5: human behavior in emergency Topic 6: characteristics of the building in the evacuation	Response to a simulated emergency test
Training for first aid team (TFAT)	Topic 1: first aid Topic 2: transport of the injured Topic 3: basics of first aid	Application of a cardiorespiratory resuscitation procedure, using a training manikin, mask, and insufflator

two different moments: M1 (after the education/training action) and M2 (three weeks after the education/training action), to understand the influence of time in the knowledge acquisition. For practical assessment, the researcher established specific criteria's and each one was classified as Insufficient (score = 1), Sufficient (score = 2), Good (score = 3), and Very Good (score = 4).

2.3 Emergency Scenarios

All workers developed an activity called "Emergency Scenarios". Three emergency scenarios were presented to workers, namely: $\mathbf{ES_1}$—Fire; $\mathbf{ES_2}$—Bomb Threat; $\mathbf{ES_3}$—Work Accident. The scenarios were presented to each emergency response team and then to the group of workers not integrated into the teams (NI) (n = 10), to test the effectiveness of specialized training. The methodology used in this activity was based on Li et al. [5]. In this activity, the researcher was responsible for presenting the theme and context of each scenario. All participants received three different cards for each scenario. Table 2 present the description of each card.

Table 2 Description of cards

Card type	Description
Information card	Important information created based on the context characteristics and which can help in the decision-making process
Action card	Actions to carry out; actions that the actors must develop, based on their function, and on the information obtained
Decision card	Information that the emergency was solved; and that actors finish the action

The groups had a brainstorming to defined the intervention sequence in each emergency scenario, considering that it was a real situation. The researcher replied to the information cards and only showed the correct sequence on the end of this activity, to not compromise the group performance. The assessment of this activity considered the time spent to solve each scenario and the sequence the cards.

2.4 Data Processing and Analysis

The data obtained were analyzed based on the descriptive statistics, using the mean percentages and standard deviation obtained in each assessment test. The mean percentage of correct answers by groups were determined to M1 and M2. *Wilcoxon*'*s* test was used to verified differences between the results obtained in the different assessment moments (M1 and M2). As regards to the emergency scenarios, the time (in seconds) since the scenario presented to the delivery of the decision card by the participants, was determined. The percentage of correct cards presented and the sequence of cards was also determined in this activity.

3 Results and Discussion

The results of assessment test applied to all participants (n = 22), in the M1 and M2, revealed that there was an increase of average classification from the M1 (84.77(±6.07)%) to M2 (89.09(±5.03)%). The participants had worst results in the Topic 4 (First Intervention Equipment), with an average of 87.50(±10.21)% for M1, mean of 84.38(±15.73)% for M2. In the practical component of this training activity, it was verified that the greatest difficulty was the identification of emergency exits. The difficulty presented may be related to the fact that participants identified the nearest emergency exits in space and ignored the others. According to Wang et al. [6], despite the existence of different circuits to achieve emergency exits during an emergency, the nearest emergency exit is commonly selected, although this choice may not always be the safest.

The practical assessment of TFT demonstrated that for the criteria: "*The participant… transports the extinguisher vertically, holding the handle*", "*The participant… maintains a safe distance from the fire focus*," "*The participant… correctly removes the safety pin without incorrect downloads*, "*and*" *The participant… keeps his hands away from the plastic discharge diffuser*," participants obtained the maximum score (4). On the other hand, the criteria "*The participant… tests (first shot) the extinguishing agent*" presented the lowest scores (range between 1 and 2).

In the general assessment of TAAET, participants obtained an average score of 75.00 (±27.08) % in M1 and an average score of 91.25 (±6.29) % in M2. For specific topics, participants obtained higher scores in the Topic 1 (Alarm and Alert) and Topic 3 (Evacuation) with averages of 90.00% (±11.55) % for M1 and 95.00 (± 10.00) % for M2 and 87.50 (± 25.00) % for M1, and 100.00% for M2, respectively. This result can be explained by the increased interest of the participants about this Topic. Continuous education/training can develop new competencies and increase the capacity to adapt to new contexts [7].

The practical assessment of TFAT showed that for the criteria "*The participant... screams for help without leaving the victim*", all participants failed (Insufficient).

In general, this team obtained worse results in the assessment of practical component than the others. The complexity of the theoretical concepts and the lack of familiarity with these techniques can influence these results.

Table 3 presented the results obtained by participants in the emergency scenarios activity.

As can be seen in Table 3, FT obtained, as expected, the higher classification for order (sequence) criteria in the ES_1. FAT obtained higher classification in the ES_3 (for order criteria). In general, teams had better results in the scenarios related to their specific training. In this activity, participants were only evaluated by specific criteria's, as order and time. However, in brainstorming analysis, it is important to include different assessment topics, such as leadership skills and the ability to listen and respect other opinions.

Table 3 Emergency scenarios activity—results of the assessment

Scenario	Criteria	Team/group			
		FT	AAET	FAT	NI
ES_1	Order (sequence)	66.67%	33.33%	50%	16.67%
	Time[a]	319	599	286	591
ES_2	Order (sequence)	18.18%	36.36%	18.18%	0.00%
	Time[a]	488	239	290	236
ES_3	Order (sequence)	9.09%	9.09%	100.00%	18.18%
	Time[a]	218	159	412	204

[a]Time in seconds

On the other hand, recent studies used virtual reality scenarios to training emergency response [8–10]. These tools analyzed or determine the probability of occurrence of a specific behavior in a specific emergency and, this can be used to improve training/education programs, design safety plans and measures and determine vulnerability detection. Organization safety culture can influence a worker's safety behavior. So, according to Tharaldsen et al. [11], dimensions as safety priorities safety prioritization, safety management and involvement, safety versus production, individual motivation and system comprehension were essential indicators to analyze a safety clime.

4 Conclusion

The emergency response team training constitutes, in Portugal, a legal obligation. However, there are still gaps in the design of the best strategies to educate and train workers in this domain.

The training programs should keep workers involved and able to react to different emergency scenarios. The methodology applied in this study revealed that the integration of practical activities and brainstorming to solve specific scenarios could be an excellent strategy to improve the knowledge in the emergency response. Additionally, through the analysis of questionnaires about the effectiveness education/training program, it was verified that the participants were satisfied, considering that topics were relevant and that the program was appropriately structured. This study intends to be the starting point for the creation of specific guidelines for the development of education/training programs for emergency response team appropriate to the needs of Portuguese organizations.

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Proposal of an Instrument for the Characterization of Complex Socio-Technical Systems: A Study of an Emergency Department

Angela Weber Righi, Priscila Wachs and Tarcísio Abreu Saurin

Abstract Although the ergonomics literature often refers to socio-technical systems (STS) as complex, there is a lack of instruments for a systematic characterization of their complexity. Thus, this article presents an instrument for characterizing the complexity of STS, which allows the assessment of four attributes of complexity: large number of elements in dynamic interactions, wide diversity of elements, unexpected variability, and resilience. The article presents an exploratory application of this instrument through a case study of an emergency department (ED). Data collection for applying the instrument involved: (i) the application of 120 questionnaires, each with 22 questions, to ED staff (physicians, nurses, and nurse technicians), in order to capture their perceptions about the four complexity attributes; (ii) five interviews with professionals using the questerview technique; and (iii) 65 h of direct observations of the daily work at the ED. An exploratory factor analysis of the results of the questionnaire indicated that the initial grouping of complexity attributes into four categories was consistent, so that the proposed instrument has met the objective of characterizing the complexity. In addition to this, the wording of some questions was improved as a result of the case study.

Keywords Complexity · Socio-technical systems · Emergency department

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1 Introduction

Socio-technical systems (STS), composed of social, technical, organizational and external environment subsystems that interact with each other [1], have become increasingly complex as a result of growing and more dynamic organizations, as well as by the ever-changing external environment [2]. As a result, the literature refers this particular type of SST as complex sociotechnical system (CSSs), which presents strong complexity characteristics that permeate these four subsystems. Although all SST are likely to have some complex features, some of them, such as health care, aviation, power plants and chemical industries, have been assumed to be highly complex [3]. However, the attributes of CSSs cited in the literature present some differences regarding both the quantity and the terms used to designate them.

There is also a lack of methods to characterize the complexity of CSS, which may be due to the difficulty of quantification of complexity [4, 5], as well as the lack of consensus about what are the fundamental characteristics of CSS. In addition, although some studies present attributes of SSTC (e.g., [3, 6]), they do not demonstrate, based on primary empirical data, how real systems can be described according to the proposed attributes. The descriptions presented by the literature are often based on hypothetical cases or secondary data (e.g., [7]).

Some studies, aiming to fill the presented literature gap, have emphasized the systematic empirical characterization of complexity in STS [8, 9]. In this sense, this study aims at proposing an instrument to characterize the complexity of STS. This instrument adopts the CSS's attributes proposed by Saurin and Sosa [9]. An exploratory application of this instrument is illustrated by a case study in a hospital emergency department (EDs). Healthcare, and EDs in particular, have been one of the preferred settings for investigating complexity in STS, given their features that amplify complexity, such as time pressure, irregular demand, and overcrowding [10]. Therefore, dealing with this complexity involves a substantial physical and cognitive effort on the part of the workers [11], contributing to the high number of occupational diseases in the sector.

The present study uses Saurin and Sosa [9] as reference since the set of attributes they defined were based on a literature review that compared the proposals of 14 studies. The attributes were grouped into four categories, which have relations with each other. The **unexpected variability** is mainly a consequence of the **large number of dynamically interacting elements**, as well as of the wide **diversity of these elements**. These interactions can produce emerging phenomena, i.e., phenomena that arise from interactions between elements, independently of any central control or design [12]. The **resilience** attribute, in turn, is critical to compensate the unexpected variability. According to Hollnagel, resilience is the intrinsic ability of a system to adjust its functioning before, during, or after changes and disturbances, in order to sustain operations in expected and unexpected situations [13]. Thus, resilience implies performance adjustment and self-organization to deal with manifestations of unexpected variability [14].

2 Research Method

2.1 Research Design

The case study was developed at the emergency department (ED) of a university hospital in the United States. The ED provides care for trauma and clinical patients, both adults and pediatric, 24 h a day and 7 days a week. Over 85,000 patients are treated annually. There are 82 beds, but it is worth noting that the number of beds offered does not reflect the actual number of patients assisted, since overcrowding is a routine situation. This is part of a larger study, approved by the Institution's Review Board.

The research method was divided into two stages. Initially, questionnaires were applied to the ED professionals, aiming to capture their perception about the complexity of their work environment. The results of these questionnaires were analyzed through descriptive analysis and multivariate statistics, using Exploratory Factor Analysis (EFA), through SPSS software, version 18.0. The internal consistency among the twenty-two variables was verified by Cronbach's alpha, which generated a value equal to 0.799, indicating a good reliability. The staff directly involved in the patient's care (259) were invited to answer the questionnaire and 131 answered it (50.58% of the total population). A total of 120 questionnaires were included for the analysis, since they were completely filled. In the second stage, five interviews were conducted, using the questerview technique [15]. For that, the questionnaire applied in the previous step was used as reference to conduct the interview. The questionnaire answers were discussed to better understand the reasons for the responses given [15]. The interviews were analyzed through the technique of content analysis [16]. In addition, 65 h of non-participating observations were carried out, essential to understand the context and how the professionals deal with it and execute their activities.

2.2 Complexity Characterization Instrument

The proposed instrument is a questionnaire composed by 22 questions related to the four attributes identified by Saurin and Sosa [9]. The questions are distributed as follows: (i) large number of elements interacting dynamically—5 questions; (ii) great diversity of elements—3 questions; (iii) unexpected variability—10 questions; (iv) resilience—4 questions. The greatest number of questions associated with unexpected variability stems from the nature of this feature, which emerges from various sources of uncertainty. When reading the statements, the respondents should indicate, in a continuous line of 15 cm, how much they agreed with the statement. This line had two extremes the "totally disagree" and "totally agree" anchors. The instrument was first developed in Portuguese and then translated to English.

3 Evaluation of the Proposed Instrument: EFA Results

Table 1 shows the eigenvalues resulting from the EFA and the percentage of variance that each one explains. Seven factors were identified, which corresponds to 65.4% of total variability. This value is satisfactory, since a minimum explanation of 60% of the variability is sufficient in an EFA [17]. The Cronbach's alpha obtained in each factor can also be visualized. Factor 7 did not have this coefficient calculated, because it is composed of only one question.

The EFA also allows verifying the correlation between the variables, identifying that the questions considered for each factor have a correlation with each other, an indicator of consistency [17]. However, there are different intensities in the correlation of questions of the same factor. For example, in factor 2, composed of questions Q8, Q19, Q20 and Q21, the value of the correlation coefficient of Q8 with the other factor questions, although significant (p-value < 0.01), is low for Q19 (0.283) and Q21 (0.278), showing a higher correlation with Q20 (0.423). In general, EFA results indicate a similarity between the groups of questions initially defined and the factors obtained with the statistical results.

The factors pointed out by the EFA allow to identify the groups of questions that present greater relation between them. In this way, it is possible to compare the resulting EFA grouping with the four groups of questions initially defined by the researchers. As can be seen in Table 2, the two clusters are similar, with factors 2 and 4 being associated at the same time to two of the four categories of characteristics of CSSs proposed by Saurin and Sosa [9].

Denominations were attributed to each factor, relating them to the complexity attributes. For example, factor 1, consisting of questions Q2, Q3, Q4, Q5 and Q12, represents 21.3% of the data variability, with Q3 as the most significant variable (0.829). This issue is related to uncertainty in the objectives of the activity. Thus, the denomination given for this factor is "Uncertainty", since other issues are also related to this dimension of unexpected variability characteristic, such as Q2, Q4 and Q12.

All questions related to the factor "Uncertainty" were designed to represent the characteristic unexpected variability (Table 3). Another factor that had all its

Table 1 Eigenvalues and percentage of variance explained

Factor	Questions	Eigenvalue	% variance	% variance accumulated	Cronbach's alpha
1	Q2, Q3, Q4, Q5, Q12	4.688	21.307	21.307	0.769
2	Q8, Q19, Q20, Q21	2.925	13.295	34.602	0.769
3	Q10, Q13, Q14	1.665	7.570	42.172	0.639
4	Q9, Q16, Q18, Q22	1.448	6.580	48.751	0.453
5	Q1, Q11, Q15	1.423	6.467	55.218	0.545
6	Q6, Q7	1.207	5.485	60.703	0.517
7	Q17	1.043	4.739	65.442	–

Table 2 Relationship between clusters

EFA clusters	Questions	Clusters proposed instrument
"Uncertainty" factor (1)	(Q2), (Q3), (Q4), (Q5), (Q12)	Unexpected variability
"Diversity" factor (2)	(Q8)	Resilience
	(Q19), (Q20), (Q21)	Wide diversity of elements
"Unforeseen changes" factor (3)	(Q10), (Q13), (Q14)	Unexpected variability
"External elements and feedback" factor (4)	(Q9), (Q16)	Unexpected variability
	(Q18), (Q22)	Resilience
"Dynamic interactions" factor (5)	(Q1), (Q11), (Q15)	A large number of dynamically interacting elements
"Resources and demands" factor (6)	(Q6), (Q7)	A large number of dynamically interacting elements
"Slacks" factor (7)	(Q17)	Resilience

questions related to this complexity attributes was the factor "Unforeseen changes" (Q10, Q13, Q14), representing 13.3% of the explained variance.

Thus, the 10 questions designed by the researchers to assess the unexpected variability are covered by the factors "Uncertainty", "Unforeseen changes" and "External elements and feedback", which do not have issues associated with any other characteristic of CSSs. Therefore, the distribution of the questions among three factors reflects the different aspects of the characteristic "unexpected variability".

Differently, the factors "Dynamic interactions" and "Resources and demands" are associated with the category of attributes called "large number of elements that interact dynamically" (Table 4). Again, the questions that compose the cited factors are related only to the characteristic initially proposed by the researchers. However, both factors had a Cronbach's alpha below the satisfactory (0.545 and 0.517, respectively). This result may be associated with the fact that these questions, although belonging to the same group, are related to different aspects within this category, not implying the need for high alphas to be considered as pertinent to the research instrument.

In order to identify respondents' perception of the category of "wide diversity of elements", three questions were conceived (Q19, Q20, Q21). These issues make up the "Diversity" factor, which obtained a Cronbach's alpha of 0.769 and is responsible for 13.29% of data variability (Table 5). In addition, Q8 is part of this factor (*I have autonomy to perform my activities*), which obtained a significant correlation with Q20 (0.423). Q8 was initially associated with the group of resilience characteristic issues. However, its correlation with Q20, an issue related to social diversity in the environment, can be related to the fact that professionals with greater autonomy are exposed to different situations and exchanges of information with colleagues, allowing a greater knowledge of the diversity in the environment, contributing to the decision making and resolution of unexpected situations, aspect that also favors the resilience.

Table 3 Relation between the factors "Uncertainty", "Unforeseen changes" and "External elements and feedback" and the characteristics "unexpected variability"

Attribute	Factor	Questions	Factor analysis
Unexpected variability	Uncertainty	(Q2) I make decisions under uncertainty, since the necessary information is not always available at the time I need it and it is not always accurate	0.62
		(Q3) The activities that I perform have uncertain goals	0.829
		(Q4) The activities that I perform have uncertainty in terms of methods (e.g., how to do the task)	0.805
		(Q5) Situations where a decision or an action amplifies the problem are common (i.e., it creates a vicious circle/snowball effect)	0.654
		(Q12) The cause-effect relation between my actions/decisions and their results are vague and imprecise	0.566
	Unforeseen changes	(Q10) Unexpected situations often occur while I am doing my activities	0.535
		(Q13) A small mistake (e.g., a slightly wrong dose of medication; a slightly inaccurate diagnosis) while I am working could result in a really different disclosure	0.828
		(Q14) A small variation on my activities (more workers/students under my supervision, more patients) could result in a really different disclosure	0.705
	External elements and feedback	(Q9) I often use indirect information sources to do my activities (e.g., medical records, reports from patient's family members)	0.497
		(Q16) The external environment (e.g., government actions, strikes, weather) have huge influence on my activities	0.248

The factor "External elements and feedback" is formed by Q9, Q16, Q18 and Q22 (Table 6). Two of these questions (Q18 and Q22) were designed to verify the perception regarding the resilience characteristic, presenting a significant correlation between them. However, these same two questions also present a correlation with questions related to other factors, being more significant in some cases (for example Q18 with Q11—0.327, Q22 with Q21—0.385). From this it can be inferred that sources of indirect information and external environment are important sources of uncertainty that affect how feedback is transmitted and how the organization's history evolves.

Table 4 Relation between the factors "Dynamic interactions" and "Resources and demands" and the characteristic "a large number of dynamically interacting elements"

Attribute	Factor	Questions	Cronbach's alpha
A large number of dynamically interacting elements	Dynamic interactions	(Q1) The activities in the ED are dynamic, changing over time (e.g., resource availability, types of patients, workload)	0.545
		(Q11) The activities have several control parameters (e.g., blood pressure, temperature, patient response, number of patients, number of teams, number and types of medication)	
		(Q15) My activities are inter-related with my coworkers' activities (e.g., nurse and physician)	
	Resources and demands	(Q6) There are a huge number of elements that interact during the activity (e.g., people, equipment, procedures, controls, medications)	0.517
		(Q7) My workload is different according to the time of the day, day of the week or external events (e.g., weather condition, epidemic, accident)	

Table 5 Questions related to the "diversity" factor

Attribute	Factor	Questions	Cronbach's alpha
Wide diversity of elements	Diversity	(Q19) There is technical diversity in my work environment (e.g., different types of equipment, software, medication)	0.769
		(Q20) There is social diversity in my work environment (e.g., gender, age, training/education level, marital status) of co-workers and patients	
		(Q21) There is organizational diversity in my work environment (e.g., hierarchical levels, sectors, types of procedures, shifts)	
		(Q8) I have autonomy to do my activities	

Table 6 Relation between the factor "External elements and feedback" and the characteristics "unexpected variability" and "resilience"

Attributes	Factor	Questions	Cronbach's alpha
Unexpected variability	External elements and feedback	(Q9) I often use indirect information sources to do my activities (e.g., medical records, reports from patient's family members)	0.453
		(Q16) The external environment (e.g., government actions, strikes, weather) have huge influence on my activities	
Resilience		(Q18) Feedback from others (e.g., patients' family, coworkers, supervisor), activities	
		(Q22) The way things work in this organization are a result of its history (e.g., policies of past administrators, practices introduced by past workers, public politics from past)	

4 Questionnaire Improvement

Based on this exploratory study, some changes were made in the proposed instrument. Initially, the number of questions was changed from 22 to 23, incorporating a question (Q23: my work environment is complex) with the intention of

Table 7 Questions' modifications

Pre-validation version	Post-validation version
Q8. I have autonomy to do my activities	I have autonomy to do my activities (e.g., I can decide the sequence of activities, I can prioritize the patient to be attended, I do not have to wait for instructions from superiors to decide what to do)
Q17. There is substantial slack in my work environment (e.g., equipment and team redundancy, plenty of time to make a decision; alternatives of medication)	In unforeseen situations, I usually have alternatives to perform my activities (e.g., redundant equipment and teams, time for decision-making, alternative medications to those prescribed)
Q11. The activities have several control parameters (e.g., blood pressure, temperature, patient response, number of patients, number of teams, number and types of medication) and those are related to each other	When making decisions, I need to consider several interrelated variables (e.g., patient profile, type of medication, availability of equipment to care for the patient, etc.)
Q20. There is social diversity in my work environment (e.g., gender, age, training/education level, marital status) of co-workers and patients	There is social diversity in my work environment (e.g., gender, age, training/education level, marital status)

capturing the perception of complexity of the work as a whole. The objective of inserting this question is to enable, through the use of multivariate statistical analyzes, to identify which of the other 22 questions are contributing to the general perception of complexity.

In addition, six questions (Q8, Q11, Q17, Q18, Q20, Q22) had minor changes in their wording, seeking clarity. Two other issues also had their wording changed, Q11 and Q20. These questions, although they did not obtain results similar to those mentioned in the EFA, were considered by the researchers as plausible to change for a better understanding, according to feedback received from the respondents after completing the instrument. Table 7 exemplifies these modifications.

5 Conclusions

The main objective of this study was to propose and test an instrument for the evaluation of the CSSs' attributes, since there was a lack of methods for the characterization of the STS complexity. The instrument encourages the operationalization of a theme (complexity) that has been approached more conceptually in the area of occupational safety and hygiene. In fact, as illustrated by the case study, the application of the questionnaire allows not only to characterize, but also to identify opportunities for improvement in the system investigated.

The correlations between the four groups of attributes originally proposed, represented by the four characteristics of CSSs, were greater than the correlations between the factors resulting from the EFA. This result indicates the applicability of the proposed instrument in the evaluation of the complexity of the CSSs and can be interpreted as another contribution of this study, since it empirically validates a grouping proposed in a previous study [9]. It is worth nothing that the improved questionnaire was already applied in the study of Righi e Saurin [8], in a Brazilian ED.

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Wayfinding of People with Disability and Reduced Mobility in the Urban Space

Raphael Freitas Souza and Laura Bezerra Martins

Abstract Wayfinding is a cognitive and behavioral process that incorporates the integration of the Individual Sphere (motivations, preferences, and experiences), with the World Sphere (environmental infrastructure, information and cultural values). However, this process is more difficult for People with Disabilities (PwD) and People with Reduced Mobility (PRM) due to the conditions of the physical and social environment. In order to gather scientific evidence and understand the factors which affect wayfinding and the daily journeys of PwD and PRM, a Systematic Literature Review (SLR) was conducted, with a Meta-ethnographic and Content Analysis to analyze the data. The results were organized and categorized in the Individual Sphere—with factors related to confidence and motivation, fear and anxiety, frustrations, and wayfinding and travel strategies; and in the World Sphere—encompassing environmental stimuli, infrastructure, information, and interaction with people. It is possible to conclude that the confidence of the PwD and PRM to move around the city and use urban spaces is related to a feeling of respectfulness, inclusiveness and acceptance of their differences by other actors and the environment.

Keywords Wayfinding · People with disability · Urban space

1 Introduction

Wayfinding is a cognitive and behavioral process that involves the integration of individuals with the environment and information. It includes sensations, perceptions and information processing, which lead to a person's spatial orientation and navigation [1–4]. Planning, decision-making, way-tracking and spatial recognition

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are principles of wayfinding. This spatial knowledge can be processed as a cognitive map [3, 5–8] or through practical mastery [6]. There is a connection between the individual sphere (motivations, preferences and experiences) and the world sphere (environmental infrastructure, information, cultural values and social rules) [3].

The environment, with its aesthetical, cultural and dynamic elements, can positively or negatively affect the user's spatial behavior [2, 8–10]. On the other hand, environmental information, when well-designed, can be effective in the translating and humanizing of the complexity of spaces, thus helping their comprehension by users. Therefore, it is a very important element for inclusion, due to the fact it could promote the feeling of belonging, pleasure and interest in city spaces. [8, 11].

In addition to this, awareness about accessibility and inclusion are nowadays in evidence. Based on a social model, People with Disabilities (PwD) and People with Reduced Mobility (PRM) are included in principles of diversity recognition, leading to the Universal Design concept [12]. Incapacity is not due to an individual's attributes, but to the conditions of the physical and social environment [12, 13].

In some countries like Brazil, there is a significant number of the population with impairments, and an increasing number of elderly people [14, 15], and this therefore means the issue demands more attention. Effective accessibility and inclusion are only possible when urban spaces, equipment and services are designed within a broad and holistic framework [4, 16–18] in order to offer safety and autonomy to people [16–19]. Taking this into account, it is important to understand the factors that affect the decision-making process and wayfinding behavior of people with impairments in urban places. Therefore, this research consists of a literature review of an exploratory and qualitative nature, with the following goals: To identify and classify the factors that affect the wayfinding and daily journeys of PwD and PRM in an urban space; and to identify the relationship between impairments and wayfinding. The next sections of this paper show the methods and techniques used in this study and present the results and discussions.

2 Methods and Techniques

After analyzing the subject under discussion, a Systematic Literature Review (SLR) was conducted in order to gather scientific evidence [20]. It was based on using the strict criteria of inclusion, exclusion and quality [20–23], and which specifies the approach of the studies (period, population, places, situation and the type). In accordance with these criteria, the SLR was conducted in two stages [20, 22, 23]:

- Review planning: Definition of the goals, and the research issues; the basis of the primary study resources; the research strategies; inclusion, exclusion and quality criteria; and the way that the data are extracted, analyzed and synthetized.

- Review execution: The definitions are applied and tested, and the research is synthesized, with the objective being to summarize and systematize the results through content analysis [24] and meta-ethnography [20, 22, 23].

3 Results

Based on the definitions of the methodology, the research was undertaken on the Capes Portal, a Brazilian electronic library repository for science and technology, which includes some international data bases. The keywords used were: decision-making process; wayfinding; environmental perception; disability; behavior; pedestrian; urban mobility; preferences; travel/trip; confidence; satisfaction. Through a combination of these keywords and their synonyms, the search at first found 2533 results. After applying the selection criteria (see Table 1), 24 research papers were chosen.

4 Discussion and Conclusion

The data analysis and the definition of the factors involved were based on two classes of analysis: The Individual Sphere and the World Sphere [3]. The factors were classified as facilitators (F), inhibitors (I), and varying (V). Each factor was related to the types of disabilities or impairments mentioned by the authors: Autism (A); Cerebral Injury (C); Elderly people (E); Physical-motor (M); Parkinson's (P); Visual (V); General (G). In the Individual Sphere (see Table 2), the factors were

Table 1 Selection criteria

	Inclusion	Exclusion	Quality
Period	15 years (2003–2018)	–	• Peer reviewed • Consistent methodology • Good descriptions of the research elements and findings • Relevant and reliable findings with justified conclusions
Public	Pedestrian (PwD; PRM; older people)	Without impairments; children; car drivers; cyclists	
Place	Urban space in general; Public places with relevance for daily journeys	Private places such hospitals and schools	
Situation	Daily journeys and use of public spaces	Emergencies; atypical situations	
Type of study	Papers in journals; Empirical and ethnography; Essentially qualitative and exploratory; User-focused.	Proceedings papers; Quantitative studies; Literature reviews; Studies conducted in simulators; Designing of solutions	

Table 2 Individual Sphere: Factors, Impairments—Autism (A); Cerebral injury (C); Elderly people (E); Physical-motor (M); Parkinson's (P); Visual (V); General (G); Classification—Facilitators (F); Inhibitors (I); Varying (V)

	Factors	Impairm.	Cl.
Confidence and motivation	Autonomy in daily journeys and tasks	E; P; V	F
	Environmental familiarity	G	F
	People's company, help and support: Safety and incentive	C; E; P; V	F
	Infrastructure: Close facilities, recreation areas, safe pathways	G	F
	Information: planning and environmental comprehension	G	F
	Attitude/Behavior/Treatment of other people	G	F
	Motivations of the journeys – Leisure or work	G	F
	Moderate presence of people in the streets (feeling of safety)	E	F
	Aesthetical Perception due the organization of the City	G	V
Fear and anxiety	Fear of getting tired or lost, or insecurities due to medicine	C; E; P	I
	Night journeys: Fear of crime	E	I
	The environmental aesthetics and the spatial disposition of the buildings can affect the perception of the fear	E	I
	Crowds: Source of anxiety and fear for different reasons	G	I
	Reports of others: Can promote a feeling of fear in community	E	I
	Unsafe conditions: Fear of injury due to falls or traffic	G	I
	Too much stimuli: Source of anxiety and confusion	G	I
	Constraints on asking for help and company	C; P; V	I
Frustrations	Lack of privacy and social opportunities due to dependence on others	M; V	I
	Lacking in recreational and social activities due to poverty	M; V	I
	Rude and intolerant attitude of others	C; E; M; V	I
Wayfinding/ travel strategies	Make previous visitations with assistance to get familiar with a new place or new route	V	F
	Make efforts to memorize the features of places	V	F
	Wayfinding through multisensorial environmental stimuli	V	F
	Egocentric wayfinding/Corporal and sensorial awareness	P; V	F
	Go out near home or in familiar places	A; C; E	F
	Avoid crowded places	G	F
	Ask information from others	E; V	F
	Get the information: maps, sound systems, websites, apps	V	F

categorized as Feelings—Confidence and Motivation; fear and anxiety; frustrations; and Wayfinding and Travel Strategies. On the other hand, the World Sphere factors (see Table 3) were categorized as the following: Environmental stimuli; Infrastructure; Information; and Interaction with people. From the results, it was possible to verify some similarities between the factors, but their effects varied depending on the kind of impairment. The major issues were due to the fact that the world, in general, isn't a friendly place for people with disabilities.

Table 3 World Sphere: Factors, Impairments—Autism (A); Cerebral Injury (C); Elderly people (E); Physical-motor (M); Parkinson's (P); Visual (V); General (G); Classification—Facilitators (F); Inhibitors (I); Varying (V)

	Factors	Impairm.	Cl.
Environmental stimuli	Associated to a context: Allow inferences	E; V	F
	Interactions of people and things with different types of surface	V	F
	Proximity, direction, orientation: Give the dynamic inform	V	F
	Associated to a specific place: Very useful in identification	E; V	F
	Distortions: It complicates to gauge position and location	V	I
	Too much stimuli: cause stress and confusion	A; C; P; V	I
Infrastructure	Green and recreation areas around home	E	F
	Places to rest and seat along the way	E; P	F
	Facilities around home	C	V
	Environmental aesthetics; Organization of the city	E	V
	Narrow/confusion pathways; or lack of them.	E; M; P; V	I
	Poor conditions of pathways; presence of obstacles	M	I
	Lacking in wide and systemic accessibility	M; V	I
	Elevators, ramps and footbridges in difficult locations	E; M; V	I
	Lacking in safe crossings	E; M; V	I
	Poor quality of urban services	G	I
	Lack of protection against the traffic	E; M; V	I
Information	Assistive devices and GPS	V	F
	Audio Systems giving information like next bus stops	V	F
	Technology: Useful, but could be challenging for some people	E; V	V
	Outdated, incomplete and unclear information	V	I
	Information desks which are difficult to access	M; V	I
	Insufficient information; Inadequate position of information	M; V	I

(continued)

Table 3 (continued)

	Factors	Impairm.	Cl.
Interaction with people	Presence of friendly people	E	F
	Friends, relatives, guides, volunteers: Support, safety and stimuli. But could reduce the privacy and social opportunities	C; E; M; V	V
	Crowds; commercial areas; alcoholic people	A;C; E; M	I
	People leave obstacles on sidewalks	G	I
	Intolerance, lack of empathy, patience; unfriendly behavior	G	I

Most of the elderly people, for example, really appreciate getting out of their homes into the neighborhood where they live, and the presence of other people in the streets [25, 26]. However, they feel more vulnerable. Therefore, the sense of fear (related to crime and physical safety) is perceptibly more acute for these people, and could be aggravated by aesthetic perceptions, the experiences of others, conditions of the infrastructure, crowded places and the time of day [26, 27]. Fear/anxiety could be related to some insecurities caused by the impairment, like social and stimulus intolerance (autism) [28], cognitive fluctuation (Parkinson's and cerebral injury) [29, 39], concern about falling (elderly people) [34] and being afraid of collisions with traffic and other people (all the groups) [30–35].

In consideration of this, PwD and PRM have used a variety of wayfinding and mobility strategies in their daily lives. One way is body awareness, which helps to identify one's position, which is very useful for people with visual impairment [35, 36], and having mobility control, like people with Parkinson's [29]. As a result of visual impairment, some people think that it is useful to make a previous visit to an unknown place or route using a special/private means of transport or with the support of people, to gain familiarity and confidence [37, 38]. As a consequence of restrictions caused by impairments, people with autism, Parkinson's and cerebral injury, don't deal well with changes and too much stimuli. Therefore, they might prefer going out to close and familiar places [28, 29, 39]. Another useful strategy is to be aware of the multisensorial stimuli which help the wayfinding process. Although it could be very useful in identifying places, including their features, and one's position [7, 8, 32, 36, 38, 40–42], the stimuli are susceptible to distortions and masking.

On the one hand, it's essential that urban places have a broad and systemic design in their infrastructure as much as in their environmental information. The infrastructure needs to offer accessible and safe conditions, and good spatial disposition of equipment, elements and footpaths, according to Universal Design principles [12, 30, 44–48]. It is also important for the environment to offer incentives and give confidence to users, such as the presence of close facilities, stores, green and recreational areas [34, 45, 46]. On the other hand, the environmental information must promote, in an inclusive way, the use of public spaces and equipment, and daily journeys which are secure and autonomous within the local context [37, 43].

In addition to this, authors have pointed out that other people also have a great influence on the wayfinding and navigational behavior of PwD and PRM. They could offer assistance, and incentives [29, 37, 45]. However, asking for help and being dependent on others could be embarrassing, and thereby reduce social opportunities for PwD and PRM [37, 39]. The intolerance, the lack of empathy and bad behavior of others could also cause inhibition and constraints [30, 39].

In view of the current discussions, it is possible to conclude that the confidence of PwD and PRM to move around the city and to make use of urban spaces, are related to feelings of respectfulness, inclusiveness and acceptance of differences in the world. Therefore, it is important, for real inclusion to happen, to consider social, economic and cultural issues, city and neighborhood planning, safety and security, and the attitude of people in general. The efforts to identify the factors that affect the wayfinding behavior of the PwD and PRM, and to comprehend their necessities, is a valuable basis from which to develop measures to make urban spaces more attractive, friendly and safe for people with the most diverse characteristics. It could also be useful in developing information systems, making improvements in the infrastructure of the cities, and promoting educational actions within the population, in order to provide a better quality of life for all.

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(Post)academic Safety and Health Courses, How to Assess Quality?

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Abstract Quality of (post)academic courses on safety and health is a delicate topic. In the scientific safety literature quality of these courses is hardly an item of publications. Evaluation of (post)academic safety and health courses hardly go beyond an inventory of trainees' perception of the course, and results of examinations of course members. This paper discusses some educational literature on quality assessment, going back to the late 1950s, 1960s. These publications provide a heuristic for evaluation of education, still used today. Transfer of knowledge, skills and attitudes, learned during these courses is thereby the central point. Evaluation studies on transfer deserve more attention, for instance by assessing trainees' input in safety management of their company or organisation, and more specifically their impact on major accident scenarios and quality of safety barriers.

Keywords Education · Safety and health · (Post)academic course · Quality assessment

1 Introduction

Academic courses are evaluated in one way or another. But it is still a difficult topic, at least not a topic for scientific publications. Maybe it is a lack of tradition, financial constraints, or even worst, we do not know what to evaluate. Quality of education in safety and health can be viewed from different angles - on the part of

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participants, of the management of the course, of companies where participants are working, of the government, etc. Quality is a relative concept; the operationalization is dependent on the interest of the actor.

A definition of quality of education is not easy. In health care a definition is used [1], which might serve its purpose in (post)academic training in safety: 'Quality of safety and health education is the degree to which organisations providing these trainings and educational courses will increase the likelihood that desired educational goals are reached, and are consistent with current professional and academic knowledge'. Following this definition, learning outcomes are important and should be set beforehand.

Important papers on quality assessment are published sixty years ago by Kirkpatrick [2–6]. These papers are still referred to, because they are simple and easy to understand [7]: This paper is aiming to start a discussion on quality assessment of safety and health courses at universities. But first, four levels of evaluation, proposed by Kirkpatrick will be discussed.

Level 1 Reaction: Do trainees like the program? It is assumed a satisfied trainee will learn more and better. Almost all educational programs use this perspective for their course evaluation [8]. This observation is supported by results of a survey on (post)academic education in safety and health in Europe [9]. There is a downside. Trainees are sitting at the other side of the table. They lack an overview of topic presented. They are not able to judge the content, but mainly the form of the presentations offered. Some presenters can have brilliant presentations, with a zero content. This applies frequently to presenters with a commercial background. Measuring the reaction of trainees does not evaluate learning [4, 10].

Level 2 Learning: Is the content of the course understood by trainees? Knowledge can be tested in various ways. Trainees can give individual performances, participate in group work, and take an active role in discussions during presentations [11]. And most (post)university courses will have some sort of examination, often based on project work of field work performed the trainee. In some examinations or evaluations, skills and attitudes are assessed [12]. A complication is that evaluation tools in practice are mostly restricted to so-called 'internal tools', only monitoring reactions of trainees and individual teachers.

Level 3 Behaviour: Is the knowledge obtained by the course applied in their jobs? This is already a difficult level of evaluation, for it requires either contact with the trainees company, followed by interviews of trainees, bosses of trainees, co-workers and company documentation performed by the trainee. Another option is a questionnaire. But this method can produce rather unreliable results. Without any contact of the trainees company, answers to questions are difficult to interpret. Not many organisations organise such an evaluation.

Level 4 Results or impact: Are companies or organisations with trainees successful finished a course safer, or healthier? This is a difficult one. How to measure safer, or healthier? In safety incidence frequency rates are biased, unreliable, and subject to all sorts of variations. Also Kirkpatrick has mentioned the pitfalls of outcome parameters [13]. Nice recent examples on the level of workers' education are studies from Yu et al. [14] and of Chatterjee and Agrawal [15]. Accident processes, or more specifically major accident scenarios, and quality of safety barriers preventing accidents might be regarded as better indicators. Trainees' input in safety management of the company or organisation can be monitored specifically on its impact on these accident scenarios and safety barriers. Quality of (post) academic safety and health courses is then put in the interest of companies providing course members.

The four levels of Kirkpatrick evaluate the output and outcome of courses. Donabedian [16] has proposed an evaluation scheme with input-process-output-outcome, also evaluating the content and processes offered in the course. The input or infrastructure refers to the state of the art of knowledge provided by the course and the quality of the teachers. Course organisers must have an overview of the course domains taught, being able to select up to date teachers and giving feedback. Also the educational process and its output is addressed by Donabedian:

(a) the relevance and quality of the selected educational activities and learning materials: are these conform to the learning objectives, are they complete and valid?
(b) the quality of the teaching performance such as of interactive learning and of learning by doing. Are all participants involved in active learning?

2 Transfer of Education

The logic of Kirkpatricks' levels has been questioned. A positive reaction of trainees does not include an evaluation of learning in the sense that the trainees have understood principles, models, essential facts, theories and techniques taught [4, 17]. Therefore, the second and third presentations in Fig. 1 do not show an arrow between reaction and learning. Also the relation between learning and behavior on the job is not obvious.

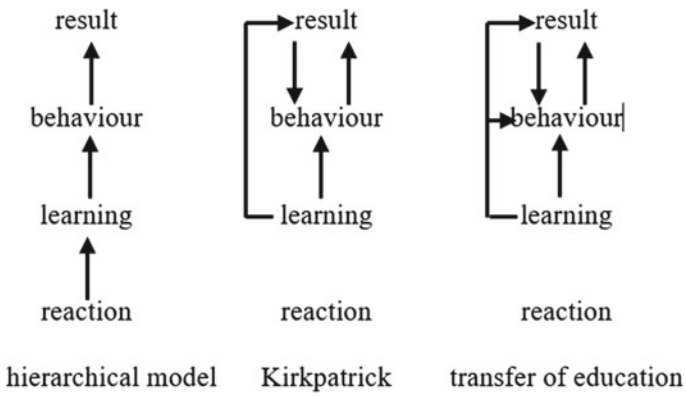

Fig. 1 Educational models [17, 18]

From the 1990s onwards literature puts more emphasis on transfer of education. Transfer means the effective application of knowledge, skills, and attitude learned in courses, on the job. This means the trainee needs to recognize and improve his or her shortcomings. Transfer can be evaluated, as explained under level 4.

3 Evaluation of Outcomes

In general people tend to continue behaviours, perceived to be effective, even if reality tells them otherwise. This means the behaviour and results levels of Kirkpatrick are interdependent [18]. Result evaluation is cumbersome, and not always possible. A before-after study design, or 'interrupted time series design', e.g. a comparison of safety records in one year before and in one year after the course may show a reduction. A causal relation between the education and these figures is questionable. Statistic variability and various forms of bias can play a role [19]. Evaluating job relationships between middle managers, and front line workers is another option [6, 13, 20]. There are also comments on the levels proposed. Studies using Kirkpatricks' levels show different effects on different levels. Many academic courses only evaluate level 1 and 2 [21]. This can be caused by difficulties in research design, time, or funding, or even disinterest of course organisers, or company's' trainees are working. Maybe Kirkpatricks' model is never meant to be more than a first, global heuristic for education evaluation. As such it has done well [18]. Looking at the low number of publications in scientific literature, addressing quality of courses, it seems this topic is not sexy enough for researchers [17, 18, 21–24].

4 Evaluation in Daily Practice

A scientific evaluation of a course only aims at a few aspects, and is addressed to a wide audience. The focus of an evaluation of daily practices covers more aspects. However, conceptually differences are not that big. In both cases clear and realistic aims and learning objectives are needed for an evaluation. Kirkpatricks' levels are a point of reference. Additional topics are offered by Donabedian, like quality of teachers, learning infrastructure, the quality of content, and of teaching and assessment methods. The combination of both authors are coming close to the definition of quality mentioned in the introduction. Authors of this paper recommend to course organisers to widen their scope, and include all four levels of Kirkpatricks' as well as Donabedians' topics. Evaluation studies of (post)academic courses on safety and health deserve more attention, more time and funding.

5 Scientific Evaluation

Scientific evaluation have two great advantages (1) the reliability of the results and conclusions is much better than in practice evaluations, and (2) results are disseminated under a very wide audience, especially when submitted to a database of scientific literature, like PubMed. Articles on evaluation studies are find and used by experts all over the world. Also studies with low numbers of participants are relevant. Author recommend both, better evaluations in practice and more scientific evaluation studies.

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Collaborative Robots

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Abstract Collaborative robots have been redefining human-robot relationships across the manufacturing industry. Companies of all types and sizes have found strategic reasons to acquire or invest in collaborative robots. Therefore, as a central precondition, data concerning the underlying manual work processes, including information on automation requirements, needs to be collected within a formal and systematic way. There are many standardization bodies which deal with the safety in human-robot interactions and this article brings some of them.

Keywords Collaborative robots · Ergonomics · Risk assessment

1 Definitions

ISO 8373 defines robot as automatically controlled, reprogrammable multipurpose manipulator, programmable in three or more axes, and which can be either fixed in place or mobile for use in industrial application. Although robots have revolutionized some jobs in manufacturing, the implementations consistently seem to share a characteristic: they are usually isolated from production workers by fences and signs that warn them away. Collaborative robotics is a paradigm shift. The name cobot, a contraction of collaborate and robot reflects the goal of the technology: machines with robot-like features that are able to safely collaborate with

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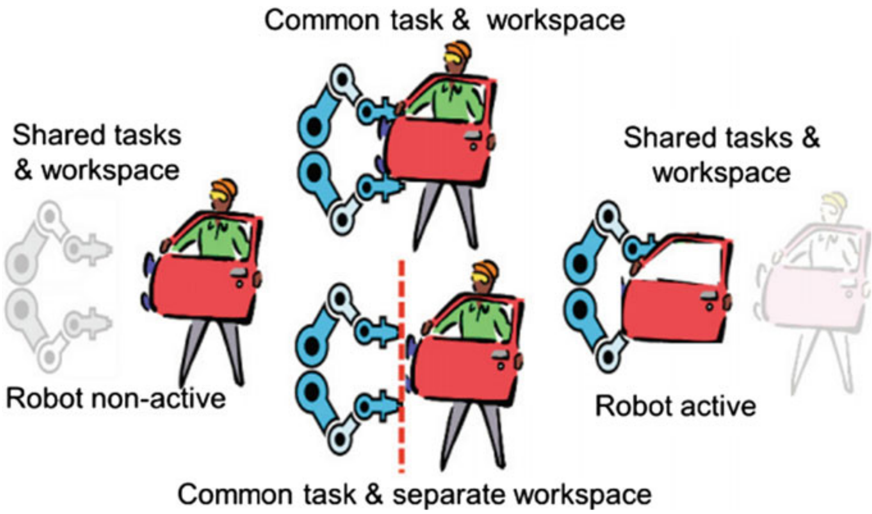

Fig. 1 Taxonomy of human-robot collaborative tasks and workspaces. *Source* [9]

assembly-line workers. It allows more interaction and sometimes contact between them, enhancing the capabilities of a line operator with robotic-type technology.

The basic mission which justifies the adoption of technological innovations is mainly to improve the competitive position. Thus, the coexistence of humans and robots seems to be a promising solution which allows sharing of workspace and tasks, causing a synergy effect between robot's precision, repeatability and strength and the intelligence and flexibility of the human being [9].

The systems of interaction between robots and humans are characterized as workspace sharing, which may or may not occur at the same time, depending on their function. In both categories, human operators and robots can perform individual or cooperative tasks. These systems can also be categorized, depending on the level of interaction. The robot and the human operator could have a common task and workspace, a shared task and a common workspace or task, and a separate workspace (see Fig. 1). In the second case, when the human operator and the robot share tasks and workspace, the relation between them is discrete [9].

Regarding the adoption of collaborative robots, studies have been carried out on simulation and programming of these robots in several industries [11], and several optimization-based approaches have been proposed to maximize the overall reward.

1.1 Collaborative Workspace

A Collaborative Workspace is a space within the operating space where the robot system (including the work piece) and a human can perform tasks concurrently during production operation (ISO 10218-1:2011) [3].

1.2 Collaborative Operation

A Collaborative Operation is a state in which a purposely designed robot system and an operator work within a collaborative workspace (ISO 10218-1:2011) [3]. There are four methods of collaborative operation and it is possible to have any mix of the four methods represented in one robot system, even all four: safety-rated monitored stop, hand guiding, speed and separation monitoring, and power and force limiting.

In safety-rated monitored stop, the premise is that in a shared space with a person, the robot does not move at all. Hand guiding indicates a condition in which the robot and person occupy a shared space and the robot is only moving when it is under direct control of the person. In speed and separation monitoring, both the robot and the person can be moving in that space, but if the robot and the person become too close, the robot stops, effectively becoming just like the first scenario (safety-rated monitored stop). In power and force limiting, there can be contact between the person and the robot, but the robot is power and force limited and sufficiently padded or otherwise, such that if there is any impact, there is no pain and no injury.

1.3 Manufacturing Safety Guidelines

Along with Industry 4.0 becoming a reality, there is concern about its impact on occupational health and safety management. Integration initiatives should combine task analysis, occupational risk dynamics assessment, workload analysis, and skill management tools [2]. Regarding the adoption of collaborative robots, studies have been carried out on the simulation and programming of these robots in several industries [11], and approaches based on optimization have been proposed to maximize the overall reward, as in Pearce et al. [10].

Cobot implementation in manufacturing demands a well-documented and accurate prediction of all potential safety issues caused by the close interaction between the human operators and the cobots. The bottom line for any collaborative robot integration is a risk assessment.

For robots working in human environment, human safety is one of the most serious and important aspects to be considered. Appropriate intrinsic and functional safety design must be employed for collaborative robots in order to reduce the human injury risks through physical human-robot interaction.

It is mandatory to define and develop a comprehensive approach for safety assessment of human robot collaboration applications which, according to Askarpour [1], include:

- Complying standards of risk analysis and robotic safety;
- Ensuring the absence of unforeseen hazardous situations during design of systems by formal verification;
- Focusing on hazards caused by operators' behavior;
- Estimating the gravity of identified hazard as a quantified value—named risk, which is computed based on detailed analysis of the whole system;
- Suggesting proper treatments known as risk reduction measures, which decrease the risk down to a negligible threshold.

Collaborative robots help eliminating the dull and repetitive jobs that can cause strain on workers. Technical assistance applications for human beings as well as collaborating human-robot systems are used increasingly to support an ageing workforce to cope with the substantial current requirements regarding industrial work. In particular, the application of service robots allows for the combination of the employee's cognitive-analytical and sensorimotor abilities with the advantages of a robot system.

In cases which safety and complexity are primary, not only do collaborative sensing robots work side-by-side with a human counterpart, but they are also able to complete complicated and dangerous tasks that traditional robots or humans simply cannot. Applications like steadying the motion of surgical tools or lab operations to prevent human error from causing unwanted motion are at the forefront of the collaborative robots industry. This paves the way for humans to rely on the inherent benefits of robots while improving complex and dangerous techniques.

2 Normative Documents

There are many standardization bodies dealing with the safety in human-robot interactions, but the most influential ones are the International Organization for Standardization (ISO).

- ISO 10218-1:2011 [3], Robots and robotic devices—Safety requirements for industrial robots—Part 1: Robots;
- ISO/TR 20218-1:2018 [7], Robotics—Safety design for industrial robot systems —Part 1: End-effectors;
- ISO 10218-2:2011 [3], Robots and robotic devices—Safety requirements for industrial robots—Part 2: Robot systems and integration;
- ISO 11593 [4], Manipulating industrial robots—Automatic end effector exchange systems—Vocabulary and presentation of characteristics;

- ISO 12100:2010 [5], Safety of machinery—General principles for design—Risk assessment and risk reduction;
- ISO 14539:2000 [6], Manipulating industrial robots—Object handling with grasp-type grippers—Vocabulary and presentation of characteristics;
- ISO/TS 15066:2016 [8], Robots and robotic devices—Collaborative robots.

The ISO/TS 15066 expands on collaborative guidance in ISO 10218-1 and ISO 10218-2: 201 and is one of the most anticipated technical specifications in the collaborative robotics realm. It was released in 2016 February and provides data-driven guidelines for designers, integrators, and users of human-robot collaborative systems on how to evaluate and mitigate risks, specifying safety requirements for collaborative industrial robot systems and the work environment, and supplements the requirements and guidance. It includes formulas for calculating the protective separation distance for speed and separation monitoring. An interesting part of the technical spec is the annex, which contains guidance on how to establish pain threshold limits for various parts of the body, particularly for power and force limiting applications. The data can then be extrapolated to determine speed limits for the collaborative application.

ISO/TR 20218-1:2018, applies to industrial robot systems as described in ISO 10218-2:2011 and ISO/TS 15066:2016, providing guidance for end-effectors in robot systems, including collaborative applications in which a robot system and operators share the same workspace. In such collaborative applications, the end-effector design is of major importance, particularly characteristics such as shapes, surfaces and application function (e.g. clamping forces, residual material generation, temperature).

A comprehensive risk assessment is required by ISO 10218-2:2011, and ISO/TR 20218-1 provides additional guidance specific to end-effectors that can be helpful when performing the risk assessment in accordance with ISO 10218-2:2011.

3 Conclusions

Cobots have been redefining human-robot relationships across the manufacturing industry. Companies of all types and sizes are finding strategic reasons to acquire or invest in collaborative robots. They are cost-effective, safe, and flexible to deploy.

The question is how to support industrial users in analyzing their specific manual work processes and planning appropriate service robotic solutions. Seeing that, as a central precondition, data concerning the underlying manual work processes including information on automation requirements should be collected within a formal and systematic way.

Based on this formal manual process modelling, hybrid or fully automated manufacturing and assembly systems using industrial service robots can be designed. Yet, it requires a formal process whereby all relevant automation parameters concerning the work systems: work task, process, input, output, human being, manufacturing equipment and external influences.

It is believed that the insertion of collaborative tasks within tasks which require high physical demand of operators presents potential for benefits by allowing the reduction of social and assistance costs related to the accident, as well as by contributing to a modernization of productive lines and the industrial sector.

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The Virtual Reality in Olive Oil Industry Occupational Health and Safety: An Integrative Review

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Abstract The impact of Virtual Reality (VR) on methods and techniques of Occupational Health and Safety is widely considered when high-tech, automatized and human risk-intensive branch involved. VR technologies albeit considered mature, require the expanding from the scientific and merely experimental visualization realm into more multidisciplinary areas especially the OHS in companies. As VR has a significant impact on improvement of occupational health and safety situation at any enterprise, it is to be adopted or absorbed by the so called traditional industries, especially agri-food ones. The VR can provide the simulation and prediction of contingency conditions not included within the risk management approach of the company and to serve for operationalizing and designing future and retrospective analysis of potential or befallen risks and human errors. This paper reviews a sample of conceptual and empirical articles in order to describe and synthesize possible approach to enhance VR use within OHS in Olive Oil industry. The main objective of the integrative study is to build new framework of the VR application in technology-based innovation within the industry. This paper will discuss the issues related to state-of-art of interactive virtual environments, especially Virtual Reality, in processes of Occupational Health and Safety in traditional agri-food industry such as Olive Oil multi-sector (olive farming, oil press, olive pickles).

Keywords Olive oil industry · Virtual reality · Immersive techniques · Occupational health and safety

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1 Virtual Reality (VR) as a Common Method in Occupational Health and Safety

Currently, companies are dealing with Occupational Health and Safety (OHS) management requirements on the three-dimensional basis. The emergent technologies such as Virtual Reality or immersive technologies are one of many ways of responding to the challenges that dynamic and exponentially growing markets impose on enterprises the new forms of dealing with risk perception within the OHS strategies [1, 2].

VR environments are highly ranked as suggested scenarios for OHS trainings and audits, demonstrations and visualizations [3–5] due to immersion and simulated reality perception perceived rather natural by technicians and executive staff. However, the employment of VR in more traditional corporative environments is still underused particularly when the perceived risk level is low or medium.

1.1 State of Art of VR in Occupational Health and Safety

Virtual Reality (VR) technology is one of rapidly evolving areas of immersive environments focused on real conditions modelling for the purposes of simulation, visualization, prototyping and factor reactiveness measurement within the specific set of elements [6–9].

As it is defined, the Occupational Health and Safety in organizations includes actions, behavior and outcomes that employees perform with in almost all tasks to enhance health and safety on coworkers, customers and the environment [10]. Thus, the simulation and interaction among the environment-defined factors become the challenge to complex industrial systems. Virtual Reality (VR) simulations become an efficient tool for training and simulation of abnormal and dangerous conditions [11, 12] as well as for solving and validation of complex problems [13]. All this makes of VR the instrument of real workplaces simulation aimed to be provide improvements of company's OHS [14–18].

Furthermore, VR models the perspective, angle of view, and acoustic and haptic factors of the environment and becomes the way of approaching reality of human information processing [7, 19, 20] close to real workspace situations taking into account human, material and financial resources [4].

Thus, for the OHS purposes, VR can be applied into wide range of solutions; the safety-centered improvement of products and processes usability [21], review of designed solutions of the human-system interfaces within potentially dangerous situations [5, 22], safety tests validation of potentially dangerous products or proceedings without human exposure [23, 24] possibility analysis of risk factors visualization [18], as well as the cause-effect relationship identification of accidents or risk build-ups [22].

Reference [25] also considered as a possible OHS approach the participatory ergonomics design (PED) applied to product and workplace design using the virtual simulation. Moreover, the VR presents a better-scaled perception of the real world solution for participatory ergonomics [26].

A complete immersive system can isolate the user from all distractions, increasing the perception of reality and, as OHS considered, improve the stay-on-track of most dangerous tasks during the work performance [27, 28].

This habitual focus of VR used in OHS management has been progressively increasing during recent years; however the most innovative solutions to the risk simulation or prevention are penetrating slowly in the heavy machinery dependent industries.

1.2 New Perspectives of Immersive Methodologies in Occupational Health and Safety

Considering the new approaches and improvements in VR technology precision and outputs, the new emergent fields of OHS has been attracted to this immersive technology. The specialized and interactive virtual environments able to offer the qualification and training on safe behavior and minimizing hazardous performance and risk assessments [14, 19, 29], the adequate task performance aligned with ergonomic design principles [30] and OHS digitalization [2, 31] are but some of new potentialities of the VR in OHS field.

Whole new opportunity to analyze the risk factors *ex ante* during the visualization and interaction with the use of VR for new devices, processes design and problems solving within the workplace, has arisen in the OHS area [32]. However, the safety devices and procedures validation in the context of real life use is not usually easy and precise. The virtual environment and risk factors simulation for the products, devices and processes development can change the actual OHS R&D landscape [33, 34].

On the other hand, the OHS knowledge and motivation could become relevant variables of safety performance within the virtual environments [35] as a collateral benefits of health and safety prevention [36–38] particularly when young workers involved [39]. However, the VR use in safety instruction and training could have an ambiguous effect on risk-perception as the participants accustomed to virtual environments of leisure, were unable to correctly estimate the hazard levels in the risk-perception [39, 40].

2 Potential of VR Implementation into the OHS Processes in Olive Oil Industry in Spain

Spain is the world's leading olive oil and table olive (pickles) producer with the land area devoted to olive farming in 2012 was 2.5 million ha and more than 300 million olive trees. It means that approx. 15% of all Spanish farm land is devoted to olive. The same ratios are represented by olive oil press and mills (according official statistics 15,411 olive oil mills in 2012), including also table olives pickles factories, what encompasses the potential and importance of olive oil industry for the Spanish economy.

Although considered as traditional during recent years olive oil industry has been experiencing a deep transformation focused on sector's technological development and design to improve the competitiveness, resource consumption and emissions derived from olive oil production. The Occupational Health and Safety in the olive oil mill and table olive industry is still relatively underdeveloped. However some studies have defined the key risks and hazards in this sector [41, 42]. The main effort on the OHS in olive oil industry seems to be aimed to implement the internal safety procedures and prevention regulations, more than high or deep-technologies wide-ranging introduction as it take place in other sectors [43].

2.1 *State of Emerging Technology-Based Methods in Olive Oil Industry in Spain*

Olive Oil Industry, particularly the olive oil mills implant the new technologies and processes within the wide range of material and extraction procedures [44]. Among them we can include the innovation based on complex series of physical, physic-chemical, chemical and biochemical transformations aimed to increase productivity and quality of product through the establishment of an innovative and sustainable plant [45].

The fundamental processes of olive oil industrial plants based on mixing, water adding and warming are the main focus for the emerging technology-based methods implementation. The evolution of sensor-equipped malexers [46–48], the continuous malaxation extraction system [44], the vibration systems on the oil yield [45], the preheating treatment of the olive paste [49], olive paste monitoring and analysis of volatile compounds inside the crusher [50] or solid-liquit extraction of intercellular substances (water, oil and antioxidants) [51] are only some of emerging technologies applied to the olive oil industry.

Similarly, the ultrasound and microwave technologies applied in the olive oil elaboration processes [52] are the growing trend within the sector. All these innovations, along with the strong emphasis on the health and safety in the workplace, have caused that most of the olive oil mills have implemented the OHS strategies or at least Risk Assessment Plan [42, 53]. Nevertheless, the use of emerging simulation or modelling technologies such as Virtual Reality or Augmented Reality is reduced and insufficiently explored both by R&D entities and by academics when olive oil industry involved [43].

2.2 Foreseeable Impact of Virtual Reality on OHS of Olive Oil Industry in Spain

The rapidly evolving technologies and relentless advances in working environments health and safety rules inevitably lead to the adoption of new potential solutions in wide range of Occupational Safety and Health (OSH) issues. The Virtual Reality can become the effective mode to respond to the challenges that dynamic and exponentially growing markets impose on enterprises the new forms of dealing with risk perception within the OHS strategies [1]. The olive oil industry in Spain is not exempt from the obligation to take much better advantage of the opportunity to empower truly efficient solutions based on VR [16, 31].

The OHS strategy of an olive oil mill or industrial plant of table olive may take advantage of VR implementation due to the prevention measures acceleration [4, 21], OHS digitalization within the integral modernization or innovation strategy [2, 54] or particularly, risk prevention knowledge acquisition through the hazard-controlled simulated virtual environment [22, 43].

In addition, the R&D processes aimed to the risk prevention and safety devices development can benefit from the VR [33, 34]. According to new technological trends dominant in olive oil industry, it is convenient to elicit in particular the study of potentially harmful effects of noise [42], vibration [45], and chemical substances exposure [50]. The OHS regulations should be implemented as a consequence of the VR risk simulation as well as the adequate maintenance systems should be carried out in the olive oil mills and table olive plants. The specific procedures and methods of machines and equipment maintenance may give an advantage to sustainable OHS strategies emerged from VR simulations.

3 Discussion and Conclusions

Although studies from around the world identify the main occupational hazards of sector-specific scope and propose the VR employment to carry on the environment and processes simulations [33, 40] as well as safety prevention trainings [29, 39, 40], the information on VR application within OHS management in olive oil industry is scarce if not inexistent. The pilot studies are required to determine the exact range of impact of VR on oil extraction processes simulation to prevent accidents and negative influence on health and safety of olive oil mill workers (e.g. noise exposure [42]).

Alongside the other emerging technologies (Artificial Intelligence, IoT, M2M) [43] in nascent phase in olive oil industry, on an extrapolated basis of other manufacturing sectors, the Virtual Reality targets revolutionizing Occupational Health and Safety trainings within the simulated environment of olive oil mill or table olive plant [16, 18] However, the main difficulty of VR solutions implementation in OHS in olive oil industry is to develop the specific skills sets to be able to perform the environmental factors modelling and to draw conclusions suitable to become the basis for the improved OHS strategies.

Furthermore, the applied research in VR use for OHS and risk prevention approach within the virtual environment interaction in the context of the Spanish olive oil industry should be conducted to provide clear evidence for the effectiveness of this technology.

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