Advances in Intelligent Systems and Computing 792

Richard H. M. Goossens *Editor*

Advances in Social and Occupational Ergonomics

Proceedings of the AHFE 2018 International Conference on Social and Occupational Ergonomics, July 21–25, 2018, Loews Sapphire Falls Resort at Universal Studios, Orlando, Florida, USA

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Advances in Human Factors and Ergonomics 2018

AHFE 2018 Series Editors

Tareq Z. Ahram, Florida, USA
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9th International Conference on Applied Human Factors and Ergonomics and the Affiliated Conferences

Proceedings of the AHFE 2018 International Conferences on Social and Occupational Ergonomics and Human Factors in Sports, Injury Prevention and Outdoor Recreation, held on July 21–25, 2018, in Loews Sapphire Falls Resort at Universal Studios, Orlando, Florida, USA

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Preface

An exploration of how ergonomics can contribute to the solution of important societal and engineering challenges, Advances in Social and Organizational Factors, discusses the optimization of sociotechnical systems, including their organizational structures, policies, and processes. It includes coverage of communication, crew resource management, work design, design of working times, teamwork, participatory design, community ergonomics, cooperative work, new work paradigms, organizational culture, virtual organizations, telework, and quality management.

The book provides research on urban infrastructures and how to shape urban spaces, including stadiums and museums. It covers warning systems in cars, voice-based interfaces, and the positive effects on manufacturing processes available from health informatics and management systems. Several chapters examine the role human factors can play in counter-terrorism efforts and in interpreting deceptive behaviors. They provide suggestions on how to improve enterprise resource planning systems and stress the importance of lifelong learning, personalized learning, and work–life balance.

Human Factors in Sports, Injury Prevention and Outdoor Recreation aims to address the critical cognitive and physical tasks which are performed within a dynamic, complex, collaborative system comprising multiple humans and artifacts, under pressurized, complex, and rapidly changing conditions that take place during the course of any sporting event. Highly skilled, well-trained individuals walk a fine line between task success and failure, with only marginally inadequate task execution leading to loss of the sports event or competition. This conference promotes cross-disciplinary interaction between the human factors in sport and outdoor recreation disciplines and provides practical guidance on a range of methods for describing, representing, and evaluating human, team, and system performance in sports and amusement park domains.

The book also highlights issues with special populations, detailing how to design and adapt products and work situations for these groups. In addition to exploring the challenges faced in optimizing sociotechnical systems, the book underlines themes that play a role in all the challenges and how they are linked to each other.

It concludes with an exploration of emotional ergonomics and the important positive effects of making people happy and healthy. With chapter authors from around the globe, the book supplies a broad look at current challenges and possible solutions. This book contains a total of five sections that cover the following topics.

I. Social and Occupational Ergonomics: Evaluation, Optimization and Job Design;
II. Social and Occupational Factors of Comfort, Discomfort, and Pain;
III. Social and Occupational Ergonomics of Stress, Mental Factors, and Musculoskeletal Disorders;
IV. Human Factors in Sports and Amusement Industry; and
V. The Present and Future of Macroergonomic Systems.

The organizers would like to thank all the authors for their contributions. Each of the chapters were either reviewed by the members of the editorial board or germinated by them. For these, our sincere thanks and appreciation goes to the members of the board listed below.

We sure hope this book contributed to increase in knowledge in the field of social and organizational ergonomics and that you find the papers in this book interesting and helpful to you and your work.

July 2018 Richard H. M. Goossens

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Ergonomic Risk Assessment of Gas Delivery Operations and Stretching Program Design

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Abstract. In manual material handling, workers are often at risk for work-related injuries and musculoskeletal diseases. This study used an ergonomic risk assessment methodology to motivate development of a worker muscle stretching program, towards injury rate reduction in gas cylinder handling. We followed a three-phase approach: (1) an OSHA log analysis of the gas cylinder delivery company; (2) a tasks analysis including ride-alongs and ERA to gas delivery operations to identify tasks posing the greatest number of risk factors; and (3) design of a job-readiness program with a focus on stretching and targeting muscles of vulnerable body segments. The study yielded a novel and productive approach to stretching program development for workplace injury risk reduction. The exercise card will be evaluated in a follow-on field test.

Keywords: Stretching program · Reminder card · Manual material handling Ergonomic risk assessment

1 Introduction

Gas products delivery operations involve demanding manual material handling (MMH) tasks. These tasks are typically completed by delivery truck drivers. A typical workday involves manual handling of a variety of cylinder types, including small oxygen tanks (weighing approximately 4.5 kg), medium-size cylinders containing nitrogen or propane (weighing between 16–32 kg), and larger liquid “dewars” (weighing up to 364 kg). Drivers often exert high forces to move cylinders and lift equipment in a delivery operation. Their bodies are often subjected to awkward posture positions while exposed to other ergonomic risk factors, such as repetitious movement and high forces. As a result of these work circumstances, drivers are at risk for musculoskeletal disorders (MSDs) and other injuries and illnesses.

In this case study, we focused on the operations of one large, international gas products company for which 34% of all recordable injuries/illnesses were attributed to overexertion (of muscles). Despite some current ergonomic controls (e.g., specially

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design handles), many of the delivery tasks maintained inherent risks, such as high force in pulling dewars. These risks motivated company interest for additional controls, including developing a “job-readiness” or stretching program as a potential MSD preventive measure.

A review of literature was conducted on corporate exercise programs revealing potential benefits of a stretching program. While a stretching program does not eliminate job risks, there is some evidence of effectiveness in controlling the rate of injury in the workforce. Costa and Vieira [1] reported benefits of stretching to include prevention of work-related MSDs, especially in high-intensity work environments. Other studies have claimed benefits of implementing stretching programs in manufacturing environments, including lower risk of musculoskeletal injury [2, 3], reduced rate and length of sick days attributable to back pain [4], and reduced workers perceived pain due to musculoskeletal injuries and illness [5]. Although the origins of the benefits of stretching has received limited scientific attention, one line of reasoning is that increased flexibility due to stretching leads to a reduced risk of work-related MSDs [6].

Considering the company’s internal ergonomics program actions and results of the prior research on stretching programs, this present work sought to address three research questions: (1) What are the most common injuries during gas cylinder deliver operations? (2) What are the risky tasks and most vulnerable body parts during the gas delivery operation? (3) How can a stretching program be designed as an ergonomic intervention to potentially control musculoskeletal injury risks in gas cylinder delivery operations? The subsequent sections describe the methodology and results of three research phases of this study. This writing also provides inferences on the findings of this process, identifies study limitations as well as directions of future works.

2 Method

The case study was broken-down into three phases. The first phase focused on assessing the OSHA logs provided by the company in order to characterize the most common injuries and body parts sustaining frequent injuries. In the second phase, researchers conducted “ride-alongs” with delivery drivers and reviewed safety training videos in order to identify the tasks completed by drivers on a regular basis. For tasks identified to pose extended periods of risk exposure, an ergonomic risk assessment (ERA) was applied. The last phase of the study used the results of the previous two phases in order to develop a stretching intervention program that could be implemented by drivers with the intent of reducing the frequency and severity of workplace injuries for the company.

2.1 OSHA Analysis

Historical injury/illness data for the gas cylinder company was analyzed with a range of dates from 2013–2015. Table 1 presents descriptive statistics on the data, including total cases, cases with days away or restricted duty, as well as days away and on restricted duty. Any cases that remained open at the time of the analysis were excluded from statistics on severity (length of injury/illness) but not frequency.

Table 1. Descriptive statistics of injury/illness data.

Total number of cases (2013–Sept. 2015)	157
Percentage of cases involving days away (Count)	10.8% (17)
Percentage of cases involving restricted duty (Count)	62.4% (98)
Average number of days away	51.7
Average number of days on restricted duty	21.4

Based on the injury descriptions included in the company's OSHA logs, each injury event was coded according to categories used in the Liberty Mutual Index [7]. Two analyses were conducted with the first looking at the injury type, while the second analysis focused on the injured body part. The categories of injury type and body parts were both identified through injury descriptions appearing in the OSHA records. Due to a lack of information on some types of injuries, similar categories were grouped together for this analysis. For example, falls at the same level and to a lower level were combined into one group for the injury type analysis.

2.2 Phase 2: Task Analysis

Ride-Alongs. In order to identify those gas delivery tasks posing high ergonomic risks to delivery drivers, ride-alongs were organized for researchers to observe daily driver task performance. (This research activity was reviewed and approved by the North Carolina State University Institutional Review Board (IRB). Consent of participants was obtained prior to the study.) Two company drivers were recruited for ride-alongs and one additional driver was observed handling gas products at a regional company delivery and retail facility. In each ride-along, researchers accompanied the drivers as they made deliveries during 8–12 h. shifts throughout Eastern North Carolina, including the coastal region. Prior to the ride-alongs and onsite observation, researchers familiarized themselves with standard operating procedures (SOPs) of the company by viewing training videos intended for drivers. During the following observation sessions (i.e., ride-alongs and onsite), the researchers took notes of risky operations and any deviations from the SOPs.

In total, ten deliveries were observed and videotaped over two separate days. During ride-alongs and onsite observations, researchers recorded drivers performing the range of delivery duties. Tasks included moving cylinders with a handcart, rolling a single cylinder, rolling two cylinders, pushing dewars, loading and unloading propane tanks, and transporting small cylinders, among other tasks (Fig. 1). Videos and observation notes were used as basis for the follow-on Ergonomic Risk Analysis (ERA).

Ergonomic Risk Analysis. The ERA methodology applied in this study was developed by The Ergonomic Center of North Carolina (ECNC). This method is based on several established physical work analysis tools, including the Borg scale [8–10], the Rapid Upper-Limb Assessment (RULA) method [11] and the Moore-Garg Strain Index [12]. The method involves qualitative evaluation of force, motion and posture in target tasks. The assessment covers a range of body segments, including: (1) neck,

Fig. 1. Left - pulling a dewar; Middle - rolling two cylinders; Right - lifting small cylinders.

(2) shoulders, (3) arms/elbows, (4) hands/wrists, (5) torso/back, and (6) legs/knees/feet. Risk factors ratings are made for each body segment within each task. A 10-point rating scale is used with higher ratings corresponding to riskier motions, forces, and postures. The force factor refers to the force required by a worker to perform an identified task. The low-risk level for force is identified as requiring no (or minimal) force representing <30% of maximum voluntary muscle contractions (MVC), while the moderate-risk level falls in the 30% to 60% range of MVC and the high-risk level requires >60% of MVC. The posture factor refers to the posture required of workers in performing delivery operations. Ratings are selected based on the postures held for the longest period during a task or in which the highest load exposure occurs. The motion risk factor takes into account the number of repetitions of movements of each body part as well as the duration for which a posture is held. A low-risk level indicates that the identified movement is repeated less than one time per minute and the posture is held for under 6 s at a time. A medium-risk level indicates that the identified movement is repeated between one and five times per minute and the posture is held between 6–20 s in each iteration; whereas, high-risk level motions are performed 6 or more times per minute and held for longer than 20 s at a time. The sensitivity of the ECNC ERA has been demonstrated in application to veterinary clinic operations and rice plowing activities [13, 14].

In this study, direct observations of delivery task performance, video recordings taken during the ride-alongs, company safety training videos, and information gathered from unstructured interviews with delivery drivers provided the basis for application of the ERA. Three researchers independently assigned risk ratings for each of the critical MMH tasks identified through the ride-alongs. The analysis was also broken-down by body segment and risk factor exposure during task performance. All analyst ratings were compiled and average scores were determined for each risk factor for each body segment in each task.

The ERA method also involves determining "body segment priority levels" as a basis for recommending ergonomic risk controls. The sum of all three average risk factor scores (force, motion and posture) for each body segment was calculated to yield the body segment priority. A body segment priority matrix was also developed to determine an overall risk priority level for each task. A total body risk score, or "Job Screening Score", was also calculated by determining the number of body segments deemed to be of low, moderate or high-risk priority for each task. The number of body segments for each priority was summed up and a multiplier was applied depending on the risk priority. Multipliers included 1x for low risk priority segments, 2x for moderate risk priority segments, and 4x for high priority segments. For example, there were 3 low priority body segments for rolling cylinders, 1 moderate, and 6 high leading to a job screening score of 29. This process was completed for all tasks. The results were used to identify those high-risk body segments and muscles for task performance. This information was use for design of the muscle stretching program.

2.3 Phase 3: Stretching Card Design

Based on the company interests for additional control measures for MSD prevention, as well as the prior research on corporate "job-readiness" or stretching programs, the methodology also involved designing a stretching program for muscles used in the gas cylinder delivery operations. The first step in program development was to identify which muscles to target with stretching exercises. Within the moderate to high-risk delivery tasks, at-risk body segments revealed by the ERA were considered along with the injury log analysis in order to identify muscle groups for stretching. For each task, all muscles for each body segment were listed and those muscles that were eccentrically contracted during task movements were selected. Muscle stretches were then identified based on physical therapy reference [15]. The number of repetitions and duration of each stretch was determined based on reference texts [15] and standard practices for physical therapists and athletic trainers.

Following muscle selection, a stretching "reminder card" was designed and prototyped for company delivery drivers to use as reference during work shifts. A review of the literature revealed that illustrated and verbally described exercise instructions had a positive effect on adherence to exercise programs, when compared to those that were only presented verbally [16]. To ensure clarity of the instructions, a pilot study was conducted with a random sample of university graduate students, including 5 native and 5 non-native English speakers. Each participant was presented with a total of eight written stretching instructions without pictorial representation and asked to perform each stretch to the best of their understanding and abilities. Participants were also instructed not to make assumptions about the intended stretch, based on prior exercise experience, but to simply follow the instructions exactly as presented on the card. After each stretching trial, a researcher judged whether the participant performed the stretch correctly and, if incorrect, demonstrated the correct stretch to the participant. The participants were then asked to identify any clear or unclear wording in the exercise descriptions and make suggestions to enhance the clarity of the descriptions. Any stretches that were performed incorrectly by more than one participant were reworded using participant suggestions. Following rewording, 5 new native English speakers were asked to participate in the same pilot procedure to verify that the reworded written stretch descriptions resulted in correct performance of stretches.

In creating graphical representations of stretches, simple body figure outlines were used to follow standard practice of physical therapy authors [15]. Following the instructions and pictorial representations, the prototypes of the reminder cards were formatted following company branding guidelines.

3 Results

3.1 Phase 1: OSHA Analysis

Results from the OSHA log analysis are summarized in Fig. 2. Overexertion and other exertions included 50+ cases, accounting for 34% of the total injury cases, more than any other category. It is important to note that in this analysis, 14 injury cases were classified as, "not enough information," due to a lack of sufficient incident descriptions in the logs. The body part analysis (Fig. 2b) revealed the hands/fingers/wrist to be the most injured body parts. Most of these injuries (43 of 48) were due to being struck against an object, or compressed by or caught in equipment.

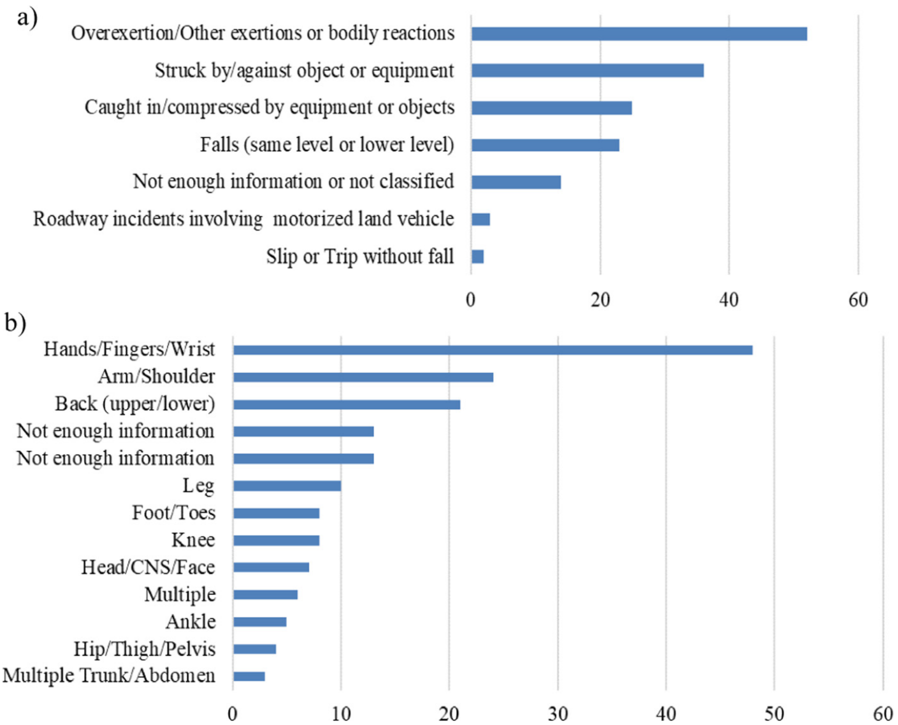

Fig. 2. Number of occurrences within reporting period by injury type (a) and body part (b)

The next two most commonly injured body parts, the arm/shoulder and the back, were primarily impacted by overexertion incidents. It is important to note that in this analysis, 13 injury cases were also classified as, "Not enough information," due to limited descriptions in the OSHA 300 logs. Consequently, additional hands/fingers/ wrist might have occurred.

3.2 Phase 2: Task Analysis

In general, observations from the ride-alongs revealed the MMH tasks to pose ergonomic risks for operators. For example, pulling dewars involves excessive force due to the weight of the object and often the necessity to move the dewars up a ramp; whereas, rolling cylinders involves awkward postures at the wrist and highly repetitive flexion/extension of the wrist. The video analysis of ride-alongs revealed specific tasks to pose extended periods of risk exposure and repetition, motivating the need for additional evaluation. These tasks included pulling a dewar, rolling two cylinders, and lifting small cylinders (one-handed without an ergonomic handle).

Figure 3 presents the total body risk scores for each task. All jobs were determined to pose high (>25) or moderate (17–25) risk scores (body priority level) for drivers. According to the ECNC, jobs with a high total risk should be redesigned or altered to reduce the risk incurred by workers and a moderate rating should result in administrative controls being implemented in the workplace to reduce worker exposure to risk factors. Rolling two cylinders received the highest total body priority level with a score of 28 (standard deviation (SD) = 4.65). The other two tasks, pulling a dewar and lifting small cylinders, were considered to pose moderate risk levels with a score of 18 (SD = 1.67 and SD = 7.08, respectively).

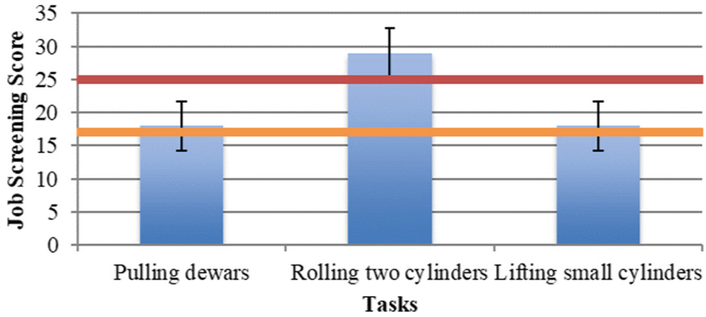

Fig. 3. Graph of overall job screening score by task (Orange line indicates upper threshold for moderate risk (score of 17–25) and red line indicates threshold for high risk (score >25)).

Figure 4 shows the sums of the mean ratings for each ergonomic risk (posture, force, motion) to create a risk score specific to each body segment and task. The risk scores provided verification of the most risky body segments during task performance, which were also identified through video analysis and direct observation.

Based on this assessment, the most at-risk segments in pulling a dewar included the shoulders, arms/elbows, back, wrists, and legs. Due to the weight of the dewar and the act of pulling the cylinder, the upper extremities and the back were identified as primary areas of concern. For dewar pulling, walking backwards also posed potential risk for both legs. For rolling two cylinders, the most at-risk body segments included the wrists, arms/elbows, shoulders, and back. Again, the upper extremities and the back were identified as areas of concern due to the weight of the cylinders. In addition, the repetition of the rolling motion for the upper extremities led to the wrists being identified as areas of risk exposure. The most at-risk body segments in lifting small cylinders included the wrists, arms/elbows, shoulders, and the back. The wrists and arms/elbows shared the most extreme risk levels due to the awkward lifting posture of the arms/elbows, ulnar deviation at the wrists, and the compounding factor of cylinder weight.

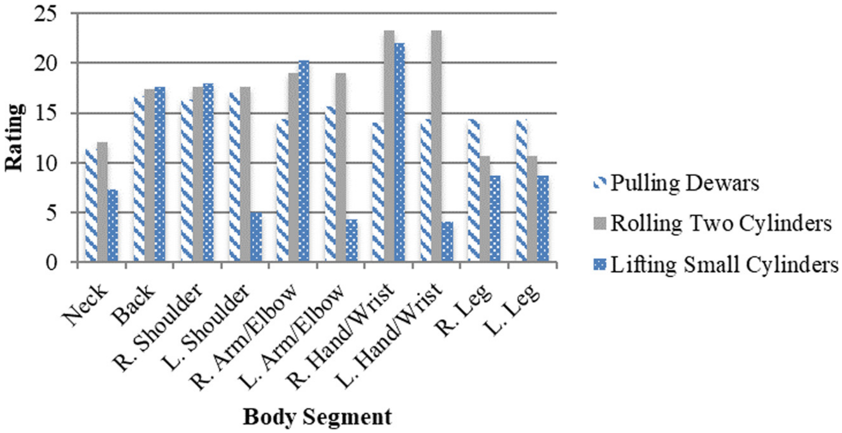

Fig. 4. Rating by body segment and task.

3.3 Phase 3: Stretching Card Design

As a basis for the stretching card design, the full process from task identification to stretch selection is detailed in Table 2. The stretches that could be accomplished in a standing posture, and requiring the least exposure to awkward body postures for muscle elongation, were prioritized for the program design. Figure 5 presents a scaled-down version of the card design (absent of company brand formatting). In the pictorial representations of the stretches, the muscle areas targeted by the stretch are illustrated by a checkered pattern.

Table 2. Task identification and stretch selection. Note: Each stretch last 20 s and is to be performed 3 times for each side of the body.

Task	Body segment	Eccentric movement muscles	Stretches that yield eccentric contractions
Moving dewars	Back	Trapezius, latimus dorsi, rhomboids	1. Parallel Arm Shoulder Stretch 2. Hamstring and Low Back Stretch
	Shoulder Upper Arm	Posterior deltoid, biceps brachii, triceps brachii, rhomboids, trapezius	1. Upper Arm Shoulder Stretch 2. Chest and Bicep Stretch
	Lower arm/Elbow	Flexor carpi ulnarus	1. Finger Flexor Stretch
Rolling two cylinders	Hand/wrist	Opponens pollicis, flexor digiti minimi, flexor pollicis brevis, abductor pollicis brevis, oppenens digiti minimi	1. Finger Flexor Stretch 2. Finger Extensor Stretch
	Lower arm/Elbow	Brachio radialis, flexor carpi radialis, flexor digitorum superficialis, palmaris longus	1. Finger Flexor Stretch
	Shoulder/Upper Arm	Brachio radialis, trapezius, posterior deltoid, biceps brachii	1. Upper Arm Shoulder Stretch 2. Chest and Bicep Stretch 3. Parallel Arm Shoulder Stretch
	Back	Trapezius	1. Chest and Bicep Stretch
Lifting small cylinders	Hand/wrist	N/A	1. Finger Flexor Stretch 2. Finger Extensor Stretch
	Lower arm/Elbow	Brachio radialis	1. Finger Flexor Stretch
	Shoulder/Upper Arm	Reach: Biceps brachii, posterior deltoid, trapezius, rhomboids, brachialis Lift: Triceps brachii, anterior deltoid	1. Upper Arm Shoulder Stretch 2. Parallel Arm Shoulder Stretch 3. Chest and Bicep Stretch
	Back	Reach: Latimus dorsi, teres major, rhomboids, trapezius Lift: n/a	1. Parallel Arm Shoulder Stretch 2. Chest and Bicep Stretch 3. Upper Arm Shoulder Stretch

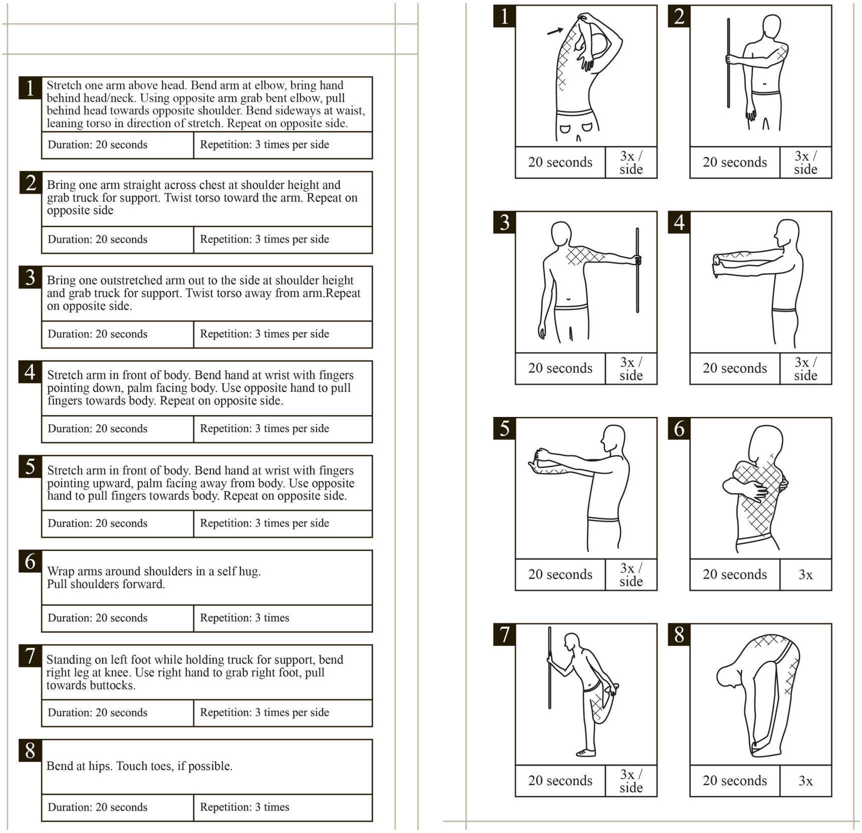

Fig. 5. The final version of the reminder card designed for the stretching regimen.

4 Discussion

The purpose of this study was to use ERA, along with injury log analysis, as basis for design of a worker muscle stretching program towards reduction of potential risk of workplace injuries. It was expected that the injury log for the delivery drivers would reveal the back to be one of the most injured areas for drivers. Bovenzi et al. [17] said awkward seated posture in truck driving and secondary MMH activities, are critical components in a multifactorial origin of back pain for drivers. The gas delivery company injury dataset for the 2-year period was partly in-line with this prior investigation. Arm and shoulder injuries were also expected to be frequent as it has been shown that frequent, heavy lifting in truck drivers is positively correlated with neck and shoulder pain [18]. The data on actual worker injuries revealed arm and shoulder impacts to be only second to hand and wrist injuries. Overexertion injuries, as recorded by the company supervisors, implied damage to muscles responsible for generating force during physical activities. Furthermore, due to the associations between driver work task activities and shoulder and back injuries, as identified in the literature, it was inferred that any stretching program should target those muscles involved in movement of the specific segments. In addition, the literature also provided a basis for the expectation that an exercise or stretching program, in advance of strenuous MMH task performance, could be an appropriate tool for further reducing the potential for overexertion injuries in the gas cylinder delivery operations.

With respect to the stretching program design, certain exercises were not included due to work environment restrictions. The stretching protocol was designed to be performed by drivers at client sites in advance of delivery operations. For this reason, stretches involving sitting or lying on the ground (a paved surface, in most cases) were excluded from the protocol, including some stretches for the low back. Given the autonomous nature of delivery driver activity, there was a need to provide written and visual instructions on a reminder card to ensure proper stretch performance. Pilot study confirmed exercise instructions were clear and would lead to drivers performing the proper stretch when working alone on deliveries.

5 Conclusion

Observations were made on gas delivery operations (ride-alongs) in order to identify the most taxing tasks on a driver's body and an ERA was applied to these tasks by multiple analysts and revealed at-risk body segments, including: wrists, arms, shoulders, and back. This information was used to further identify target muscle groups for stretching in preparation for delivery operation performance. The project culminated in the development of a focused stretching regimen and a corresponding reminder card towards reducing injury rates and severity among delivery drivers.

One limitation of the study is that the ERA was generally intended for constant, repetitive motion analysis, such as factory work. Gas delivery company driver work shifts typically consist of long drives followed by short bursts of repetitive work. As such, the motion analysis ratings were averaged over a typical 15-min delivery period rather than an 8-h work day, which may have increased motion ratings. In addition, the design of the stretching program card was intended for implementation before each delivery; however, the current regimen was found to be time consuming and additional study should be conducted to determine an appropriate schedule at which to implement the stretching card during a work shift.

Last but not least, although the benefits of stretching programs have been observed by several studies [3, 19–21], there is currently limited information on how exactly stretching can impact worker muscle physiology, exertion, fatigue and injury potential in a work environment. Such research should also identify optimal methods for implementing a workplace stretching program (e.g., training videos or pictorial representations) to ensure that employees learn correct stretches to ensure maximum benefits.

References

1. da Costa, B.R., Vieira, E.R.: Stretching to reduce work-related musculoskeletal disorders: a systematic review. J. Rehabil. Med. **40**(5), 321–328 (2008)
2. Gartley, R.M., Prosser, J.L.: Stretching to prevent musculoskeletal injuries: an approach to workplace wellness. AAOHN J. **59**(6) (2011)
3. Smith, K.: Evaluation of a stretching program to increase worker flexibility. AAOHN J. **61** (8) (2013). https://doi.org/10.3928/21650799-20130726-30
4. Kellett, K.M., Kellett, D.A., Nordholm, L.A.: Effects of an exercise program on sick leave due to back pain. Phys. Ther. **71**(4), 283–291 (1991)
5. Zebis, M.K., Andersen, L.L., Pedersen, M.T., Mortensen, P., Andersen, C.H., Pedersen, M. M., Sjøgaard, G.: Implementation of neck/shoulder exercises for pain relief among industrial workers: a randomized controlled trial. BMC Musculoskelet. Disord. **12**(1), 205 (2011)
6. Muyor, J.M., López-Miñarro, P.A., Casimiro, A.J.: Effect of stretching program in an industrial workplace on hamstring flexibility and sagittal spinal posture of adult women workers: a randomized controlled trial. J. Back Musculoskelet. Rehabil. **25**(3), 161–169 (2012)
7. Liberty Mutual: Workplace safety index. From Research to Reality (2008). www.mhi.org/downloads/industrygroups/ease/technicalpapers/Liberty-Mutual-2008-Safety-index-most-disabling-injuries.pdf
8. Borg, G., Ottoson, D.: The perception of exertion in physical work. In: Wennergren Center International Symposium Series (1986)
9. Borg, G.: Psychophysical scaling with applications in physical work and the perception of exertion. Scand. J. Work Environ. Health **16**, 55–58 (1990)
10. Borg, G.: Borg's Perceived Exertion and Pain Scales. Human Kinetics, Champaign (1998)
11. McAtamney, L., Corlett, E.N.: RULA: a survey method for the investigation of work-related upper limb disorders. Appl. Ergon. **24**(2), 91–99 (1993)
12. Steven Moore, J., Garg, A.: The strain index: a proposed method to analyze jobs for risk of distal upper extremity disorders. Am. Ind. Hyg. Assoc. **56**(5), 443–458 (1995)
13. Rogers, M., Kaber, D.B., Taylor, K.: Identifying and evaluating risk factors for musculoskeletal disorders in equine veterinary work. In: Proceedings of the 2012 Applied Human Factors and Ergonomics Conference. Taylor & Francis CRC Press, Boca Raton (2012)
14. Swangnetr, M., Namkorn, P., Phimphasak, C., Saenlee, K., Kaber, D., Buranruk, O., et al.: Ergonomic analysis of rice field plowing. In: 4th International Conference on Applied Human Factors and Ergonomics, San Francisco, CA (2012)
15. Kisner, C., Colby, L.A.: Therapeutic Exercise: Foundations and Techniques. F.A. Davis, Philadelphia (2007)
16. Schneiders, A.G., Zusman, M., Singer, K.P.: Exercise therapy compliance in acute low back pain patients. Man. Ther. **3**(3), 147–152 (1998)
17. Bovenzi, M., Rui, F., Negro, C., D'Agostin, F., Angotzi, G., Bianchi, S., Rondina, L.: An epidemiological study of low back pain in professional drivers. J. Sound Vib. **298**(3), 514–539 (2006)
18. Magnusson, M.L., Pope, M.H., Wilder, D.G., Areskoug, B.: Are occupational drivers at an increased risk for developing musculoskeletal disorders. Spine J. **21**(6), 710–717 (1996)
19. Goldenhar, L.M., Stafford, P.: If you've seen one construction worksite stretch and flex program… you've seen one construction worksite stretch and flex program. J. Saf. Res. **55**, 73–79 (2015)

20. Elberson, K.L., Daniels, K.K., Miller, P.M.: Structured and nonstructured exercise in a corporate wellness program. A comparison of physiological outcomes. Outcomes Manag. Nurs. Pract. **5**(2), 82–86 (2000)
21. Bernacki, E.J., Baun, W.B.: The relationship of job performance to exercise adherence in a corporate fitness program. J. Occup. Environ. Med. **26**(7), 529–531 (1984)

Evaluating Training for Manual Handling in the Workplace

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Abstract. This paper describes ergonomic interventions in MMH as well as the challenges and difficulties faced by practitioners.

After four days of training, 13 practitioners were evaluated during 13 interventions in MMH. The methodology was based on multiple case studies using different data collection tools: 1. Observations of training activities; 2. Logbooks; 3. Semi-directed interviews.

The trainer-practitioners (TP) faced challenges such as the variety of contexts and MMH tasks. They needed to adapt both the content and training methods to show apprentices how to deal with diverse situations. Training time was short (less than half a day (10/13)), as were the sections devoted to motor skills (less than 50% of the session). Alternative training methods were set up that were based on workers' know-how, that were adapted to workplaces, and that went beyond stereotypical or generic training. However, the trainers were limited in their actions due to the small amount of leeway they were provided regarding the availability of workers, group size, and the ability to make changes.

Keywords: Participatory training · Handling principles
Musculoskeletal disorders · Manual material handling · Ergonomic intervention

1 Introduction

1.1 Manual Material Handling Risks

The risks involved in manual material handling (MMH) have been known for many years and multiple studies have indicated the positive association between MMH activities and back injuries [1–3]. In the Province of Quebec, numerous workers have reported musculoskeletal pain (72.3%, EQCOTESST; [4, 5]). Workers with the specific job title of "manual handlers" - who numbered 35,460 in 2011 in Canada (Statistics Canada) - reported that their work is one of the first causes of musculoskeletal disorders (MSDs) for the majority of them (55%).

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1.2 Training: A Noteworthy Path for Prevention

For many years, training has been a preferred choice in the workplace for preventing handling risks. However, mixed results concerning its impact on the reduction of risks have been reported in various meta-analyses [6–8]. In fact, these studies have shown that training sessions for MMH have small or no impacts on reducing MSDs. In particular, it has been shown that handling advice has little effect in the medium- or long-term [7], that training does not necessarily ensure that employees will transfer their new knowledge back to the workplace [8], and finally, that individual training ("fitting the worker to the task") is less beneficial than a braoder approach [6].

A recent study likewise showed that the traditional approach focuses mainly on safety and has as its the mantra *to keep the back straight and bend the knees* [9]. This approach is highly prescriptive and offers workers few alternatives (i.e. manual handlers learn one "good way to do it" and are supposed to use it in every situation). This approach is essentially based on changes in the workers' behavior and proposes very few elements for a more general risk prevention approach. According to Denis et al. [9] these results unquestionably show that programs whose content is based on the application of safety techniques do not produce encouraging outcomes [9].

1.3 A New Approach to Material Manual Handling

It was in response to these observations that a new approach called integrated prevention strategy for handling (IPSH) was proposed [10]. The IPSH follows upon numerous studies focusing on diverse populations of manual handlers (e.g., garbage collectors, [11]; blue collar workers, [12]; warehouse workers, [13]; warehouse clerks, [14]) and on the mitigated results observed following training. The present approach is based on various intervention mechanisms likely to reduce MSDs. As the goal is to propose alternatives to what is currently offered, this paper focuses on three, more distinctive intervention mechanisms, namely: (a) innovative training content adapted to the work activity that aims to develop the workers' skills; (b) setting of the training course in a more general intervention;[1] and (c) the participatory, in situ nature of the approach. These three mechanisms will then serve as basis to the presentation of the results in the present paper.

1.3.1 An Adapted Content: Handling Principles

The approach aims to develop the skills of the manual handlers so that they can meet both high production requirements and varying work situations in complex and dynamic environments while all the while protecting themselves from the possible development of medium- to long-term MSDs. This approach is based on handling principles that guide manual handlers rather than on prescribed movements to be applied in all situations like the currently taught, traditional content that is entirely based on safety techniques. The principles help workers to make decisions and adapt their behavior to the MMH contexts. Eight handling principles are proposed (for a

[1] Training is one of several elements comprising prevention intervention, which is a more global approach.

detailed description and explanation, the reader can refer to [15–17]). The goal in the present article is not to describe them but rather to give a general idea. They are: 1. Postural alignment; 2. Load/body distance; 3. Weight bearing; 4. Load use; 5. Body balance; 6. Body use; 7. Transition between picking up and depositing; 8. Rhythm of movement. The basic premise is that for each principle, there is not just one way to do it, but rather a continuum of possibilities. Take for example the question of balance: people are traditionally recommended to always maintain a static balance with a firm base and an equal distribution of weight. According to IPSH, balance is seen rather as a set of choices that depend on the conditions: dynamic balance that allows for example use of the body weight in a low-risk situation, e.g., flat surface without obstacles and with a light or easy to handle load, versus a more static balance in a riskier situation, e.g., slippery or sloping surface with a large load. The challenge for the TPs is thus to adapt the training content to the specific realities of a given workplace.

1.3.2 Expanding the Intervention: Going Beyond Training

There are few or no actions that have been explored in the scientific literature other than training sessions [16]. In IPSH however, there are three elements that are emphasized to foster the adoption of new preventative behavior in workers:

- Starting with a training request, the process involves calling into question potentially restrictive work conditions that interfere with knowledge and know-how seen in training. Participation in training sessions reveals the difficult and complex situations faced by workers and identifies those with the highest risk of accidents and injuries which must be changed (e.g., fragile, difficult-to-manipulate loads; tight storage space; pathways with obstacles or slopes). These situational determinants constitute the key elements on which it is possible to act during the interventions.
- Groups responsible for intervention follow-up can be put in place so that improvements can take root in the organizations. These groups, made up of various actors such as workers, supervisors, worker representatives, training managers, operations managers (or representatives from various administrative levels) can play a transfer role to foster changes in the workplace and ensure the sustainability of the intervention.
- It is also recommended that TPs conduct a follow-up a few weeks after the training sessions. The goal here is to, for example, check with workers about the adoption of new behavior - are they having any difficulties, have they fully mastered the new skills? - but also to check that the changes to work situations have been carried out.

1.3.3 Encourage Participation: Learning Through Action

A last intervention mechanism concerns the participatory and contextual aspect that is hoped for in the learning process, in particular in the motor skills required for manual material handling. Training sessions must foster situations for the workers that are as close to real life as possible in the workplace rather than in the classroom. It is recommended that the handling and motor skill engagement be at the centre of the intervention: there is thus practice, repetition, and performance feedback. This practice should be the at heart of the training sessions: during interactions between the TPs and the manual handlers, physical handling should be prioritized over the sole transmission of knowledge. In this model (IPSH), the approach fosters a constructive dialogue between the TPs and the apprentices, and between the apprentices themselves.

These three underlying mechanisms raise implementation and transfer issues in the workplace for the TPs; one can readily see the challenges awaiting them if they opt for this approach. Creating content based on these principles means that the context and the actors involved are taken into consideration, that participation has to be won each time, and that actions that extend beyond training always have to be renegotiated. There are therefore challenges in applying this approach: it contrasts with the general rules of the traditional approach. This observation explains moreover our desire to accompany the TPs during interventions. The objective of this article is thus to show how this alternative approach to MMH risk prevention can shape the practice of TPs in various workplaces. More precisely, the present paper centers around the following question: how did the TPs implement this approach, and what were the difficulties encountered and the adaptations made? The second objective was to show how such an approach is viable in the workplace.

2 Methodology

Prior to the follow-up in the workplace, a four-day training session was given to TPs on the use of the IPSH. During a two-year post-training period, 13 TPs were followed in 13 interventions they gave to workers (10 follow-ups took place in the field, 3 others after the fact - each intervention representing one case) using a classic ergonomic approach [17]. A total of 27 h and 21 min of worker interventions were observed and filmed when possible.

2.1 Data Collection Tools

Open-ended observations were conducted *in situ* using a grid to identify elements of the intervention context (Table 1). Moreover, observation reports of the TPs' activities were conducted to determine their main training tasks during theoretical and practical interactions (n = 10 variables). Analyses (duration, frequency, task alternation) were then conducted using Observer® software. For 6 cases, verbatim transcripts of the theoretical parts were completed: in-depth analyses of references to principles were conducted. The TPs were invited to fill out logbooks (n = 13) with information on 6 themes. Post-intervention interviews from 30 to 90 min long were conducted with each TP. The goal was to validate and complete the information previously collected during the observations and with the logbooks. These interviews, recorded and transcribed, followed a preliminary outline covering the six main themes as well as themes identified in the logbooks.

2.2 Characteristics of the Observed TPs

There were as many men as women with considerable experience among the trainer-practitioners, whether it be in companies (mean: 9.3 years) or as trainers (mean:

9.7 years) (Table 2). As for their profiles, most of the TPs had studied in ergonomics (10/13) and held positions as ergonomists or occupational therapists, whereas a smaller number worked as OHS counselors (3/13). They also came from various backgrounds: risk prevention organizations in Quebec (5/13), consultant services (3/13), private enterprise, and self-employed workers. The participating TPs thus covered a wide range of sectors in the Quebec prevention network, worked in different private or public contexts, and had to deal with multiple issues.

Table 1. Summary of the data collected with three data sources.

Collection tools	Data collected
Observations in situ	
Observation grid	Context and description of the interventions: participants and group size, length of time, goals, company context, description of MMH activity and loads, work activity and production methods
Observation reports	10 variables to describe the TP's activity: introduction/explanation of concepts/in-class analysis/in-class workshop on motor skills/field analysis/field workshop on motor skills/open discussions/problem resolution/conclusion/debriefing
Logbooks	6 themes covered: training context/training activity/pedagogical model used/participation of workers and company in the intervention/effects/analysis of one's own work
Interviews with TPs	6 themes covered, questions adapted according to previously collected information: training context/training activity/pedagogical model used/participation of workers and company in the intervention/effects/analysis of one's own work

Table 2. Characteristics of the participating trainer-practitioners.

Characteristics of the TPs (n = 13)	
Gender	
Male	5 (38%)
Female	8 (62%)
Mean age	41.3 (±10.23)
Field of study	
Ergonomics	10 (77%)
Other	3 (23%)
Type of organization/Employer	
Public health/Joint sector-based associations	5 (38%)
Consultant service (private)	3 (23%)
Private enterprise/Self-employed worker	3 (23%)
Other	2 (15%)
Position	
Ergonomist/Occupational therapist	8 (62%)
OHS consultant	4 (31%)
Operator-trainer	1 (8%)
Mean seniority in the company (years)	9.3 (±7.00)
Mean training experience (years)	9.7 (±5.79)

N.B.: ± : standard deviation.

3 Results

3.1 Characteristics of Companies and MMH Activities

The companies where the interventions took place were mostly from two sectors - manufacturing/processing, and logistics - where manual material handling activities are widespread (Table 3).

Table 3. Characteristics of companies and MMH activities.

Characteristics of companies and MMH activities (n = 13)	
Activity sector	
Manufacturing/machining/processing	5
Logistics	4
Public services	3
Agriculture	1
Size of the company	
Large business	9
VSB, SB, MB	4
Production	
Goods	8
Services	5
MMH tasks	
Related	9
Central	4

N.B.: VSB: Very Small Business; SB: Small Business; MB: Medium-sized Business

Most of the participating companies were large (9/13) and worked in the production of goods (8/13) and services (5/13). For the majority of the participating companies (9/13), manual material handling was related to their activities (warehouses, transportation/delivery, etc.).

3.2 The Content Presented to the Participants

The analyses conducted to measure the use of principles during the theoretical presentations[2] (n = 6 interventions) show that they were amply mentioned during exchanges (477 times in total). The principles were sometimes mentioned individually and sometimes combined to describe and discuss the way workers accomplish their

[2] The principles were first designed to understand and discuss work situations. However, their use during the theoretical presentations was a good indicator for measuring their integration and their use during the training sessions, and thus for verifying if they were at the centre of the transmitted and exchanged content.

work activities. The principles were also used in different ways by the TPs, namely: to talk about the obstacles inherent in handling work and the risks of losing one's balance and falling; to illustrate how the human body works, specifically the anatomy of the spinal column and its postural alignment; and to discuss the determinants of work situations, such as the shape of a load and how to use it to one's advantage.

The two examples of verbatim that are presented below evoke these principles. Although, one need to keep in mind that it is not always the principles that are clearly mentioned but rather the concept or general idea:

> For alignment: "*Here we see that he pulled on the load and tipped it towards himself. This gives him a better alignment and, at the same time, decreases the load/body distance, which I will talk about later. Now look what he does here. Is it right?*"
> For balance: "*It's obvious that if you picked up the load here, you wouldn't have been that bent over. But you wouldn't have had as much stability or balance. So you really didn't have the choice but to grab it farther away from your body.*"

The principles were thus abundantly discussed during these sessions and allowed the TPs to extend their comments and widen the discussion with the manual handlers. The observations during the practical presentations, while being less systematic, also showed how the principles served as a basis for discussions about the situations in front of them.

3.3 Going Beyond Training to Firmly Fix the Intervention in the Company's Habits

Three examples were observed in which the interventions had more than an immediate impact. Intervention follow-up – TPs were able to return to the organizations and consult/interact with the workers and other actors a few weeks after the training sessions. This was possible in more than half of the cases (9/13). However, these follow-ups did not validate how the suggested changes at the workstations were progressing. Less than half of the TPs were able to set up a follow-up committee comprised of various actors (6/13). Finally, the carrying out of changes to work situations to reduce risk factors was the least observed element during the interventions (3/13). The changes were almost nonexistent and, when there were any, they were on a rather small scale, such as the installation of new handling equipment or the requirement for workers to wear lumbar belts. The nature and diversity of the changes were limited and poor; none of the changes occurred at the organizational level (e.g., schedules, team organization) or technical level (e.g., layout changes).

3.4 Participation of Various Actors

In general, results showed that the main goal of the intervention was to improve knowledge and awareness in almost all cases (12/13). For half of the cases, the goal was to improve the workers' skills so as to transfer learning into work activities (6/13). The goal of the interventions was rarely to change behavior (2/13), to learn motor skills through motor practice (3/13), and even less to change work situations (2/13).

The general training courses took place in both single, one-day sessions (7/13), and several, multi-day sessions (6/13). In the latter case, the participating manual handlers were able to start trying their new knowledge in the workplace and then come back in a subsequent session and ask questions and discuss with the TPs. Almost all the training combined a more theoretical part in a room with another more practical part in the field (10/13). In terms of length, they were often rather short, less than half a day total (10/13). It is not surprising that the theoretical and practical parts lasted less than half a day; the field training was thus often short. The groups often had more than 5 participants, whether this be for theory in the classroom (9/13) or practice in the field (6/13).

From a training delivery standpoint, data shows that participants involvement in the theoretical parts of the training was rather poor - they were essentially in a passive listening mode - and that these sessions lasted a bit longer than the practical parts (Table 4). The results indicate a total length of 15 h 22 min for the theoretical parts versus 12 h 9 min for the practical parts. There was thus no specific emphasis on the participants' motor skills. Indeed there were two dominant activities in the training sessions. During the theoretical sessions, the TPs spent on average 60% of the time explaining and describing concepts (e.g., anatomy, injury mechanisms, MSD risk factors); these sessions followed a standard model for the transmission of knowledge from the TPs to the manual handlers. During the practice sessions however, 86% of the time was devoted to enhancing motor skills through the handling of loads in real-life situations. This accounted for 38% of the total training time that was devoted to motor skill practice at workstations. The TPs sometimes organized practice workshops using a particular situation (e.g., with a large, difficult to grasp load, or in a high-risk environment) or had workers repeat movements to learn motor skills. Other activities were less frequently observed; for instance, having a group conduct video analyses of various work situations was observed during the theoretical section (20% of the time). The other types of activities between TPs and participants were short in length: each activity lasted 8 min on average.

Table 4. Trainer-practitioner's activities during the training sessions (n = 10).

TP activities in training sessions	Theoretical part	Practical part	Total (n = 10)
	Total	Total	Total
Motor skills *in situ*	NA	10:30 (86%)	10:30 (38%)
Explanation of concepts	9:13 (60%)	0:09 (1%)	9:22 (34%)
Group analysis	3:05 (20%)	NA	3:05 (11%)
Introduction	1:01 (7%)	0:16 (2%)	1:17 (5%)
Motor skills in class	0:41 (4%)	NA	0:41 (2%)
Conclusion	0:25 (3%)	0:22 (3%)	0:47 (3%)
Problem resolution	0:26 (3%)	0:10 (1%)	0:36 (2%)
Debriefing	0:20 (2%)	0:08 (1%)	0:28 (2%)
Open-ended discussions	0:11 (1%)	0:14 (2%)	0:25 (2%)
Field analysis	NA	0:20 (3%)	0:20 (1%)
TOTAL	**15:22**	**12:09**	**27:31**

N.B.: This data only concerns the 10 interventions that were observed in detail.

4 Discussion

The significant risks in manual material handling (MMH) have been known for many years and the inherent human and social costs continue to be high. Companies often rely on training sessions that are essentially based on safety approaches, but data shows that the results are limited [6–8]. This is why a new intervention approach was proposed to address these problems [10]. There are several challenges in this new approach, including a longer duration, the combination of training with risk factor reduction, the adaptation of training content to work context, and an insistence on motor skills. This being said, results from the present study suggest the potential of such an approach since the initial trials were encouraging.

4.1 A Multi-faceted Approach

Follow-up on the implementation of this approach by the TPs show that it was employed in many contexts: small and large companies, coming from different activity sectors or contexts (i.e. industrial, manufacturing and agricultural sectors, and goods and services production). Handling activities take on various forms, whether it be loading skids in warehouses, moving pipes in fields, or moving metal parts in processing companies. The IPSH thus allows TPs to deal with many different contexts. MMH training has traditionally been evaluated in the laboratory using often stereotypical and simplified situations that are rather distant from real-work activities of manual handlers [5]. The literature offer few alternatives to workplaces, but the results of the present study nonetheless show that other avenues are possible. The results clearly show that IPSH proposes a different logic for interventions that can serve as an alternative to the current tendencies in the workplace.

The other dimension that supports the versatility of this approach resides in its capacity to be implemented by TPs with diverse profiles. The participants were ergonomists, occupational therapists, OHS consultants, and even worker-trainers, all of whom were able to use and adapt the approach. It revealed itself to be versatile in regards to its content, its implementation model, its intervention mechanisms, as well as, the profile of TPs who can implement it.

4.2 Diverse Uses of Intervention Mechanisms

One noteworthy observation to the present study rely on the fact that none of the three intervention mechanisms were used in the same way. In fact, it is the innovative content based on the above-mentioned handling principles that represents the biggest breakthrough seen here. Much still remains to be done however concerning the actors' participation and the increased impact of the interventions by, for example, implementing changes.

The TPs made considerable use of the principles and assimilated this new content well enough so as to be able to propose it as an alternative to traditional training in workplaces. The TPs had no difficulty using the principles as a basis on which to develop the content, just as they were able to make certain initial analyses and adapt their training content to the workplace contexts.

However, with regards to the participation and involvement of the workers in the contextual interactions, our results show that improvements in this area are still possible. The workers were not always available, and the length of the sessions shows that they were only freed up for short periods of time so as to reduce the impact on production. It would be worthwhile to reduce the size of the groups and increase the interaction time so as to enhance both motor skills practice and discussions around skills being practiced.

Extending the scope of the interventions beyond the training sessions seemed to be difficult to achieve for the TPs. There were a few initiatives made here and there, but a key aspect of the approach – the ability to make changes to reduce risks at their source – was never more than superficially implemented. This was one of the biggest limitations seen here and endeavors are underway to determine how to help the TPs increase their ability to act on this mechanism in particular.

As for the other two mechanisms, participation and integration, it is understood that the possibilities were limited by organizational decisions ensuing from the companies' situations. The TPs could do little, for example, to determine or influence the size of groups, to have access to workstations without obstructing production, and to increase the workers' participation time.

The IPSH mechanisms comprise several new elements for the actors involved in the intervention. There are new skills for the TPs to develop, new types of learning and new content for the workers to integrate, and it is recommend to extend the scope of the intervention. It is thus normal that each intervention mechanism was not implemented to the same extent. However, the more that this approach is employed in companies and understood and mastered by the various actors, the more the intervention mechanisms will take on their recommended form.

5 Conclusion

Our results show that training sessions given in the workplace can differ from the traditional models recommended in the literature. Despite certain difficulties in increasing the impact of the interventions and in fostering the workers' participation in certain situations, the TPs were able to increase and enrich the content presented in the training sessions while adapting their work to the company context. In years to come, a large evaluative research project for this new approach is planned in order to estimate its effects on manual handlers' skills, on cost-benefit, as well as on the injuries and accidents risk rates.

References

1. Gardner, L.I., Landsittel, D.P., Nelson, N.A.: Risk factors for back injury in 31,076 retail merchandise store workers. Am. J. Epidemiol. **150**, 825–833 (1999)
2. Hoogendoorn, W.E., Bongers, P.M., de Vet, H.C.W., Douwes, M., Koes, B.W., Miedema, M.C., Ariens, G.A.M., Bouter, L.M.: Flexion and rotation of the trunk and lifting at work are risk factors for low back pain: results of a prospective cohort study. Spine **25**, 3087–3092 (2000)

3. Yeung, S.S., Genaidy, A., Deddens, J., Alhemood, A., Leung, P.C.: Prevalence of musculoskeletal symptoms in single and multiple body regions and effects of perceived risk of injury among manual handling workers. Spine **27**, 2166–2172 (2002)
4. Stock, S., Funes, A., Delisle, A., St-Vincent, M., Turcot, A., Messing, K.: Chapitre 7: Troubles musculo-squelettiques: enquête québécoise sur des conditions de travail, d'emploi et de santé et de sécurité du travail (EQCOTESST). IRSST, Montréal, R-691, pp. 445–530 (2011)
5. Vézina, C., Cloutier, E., Stock, S., Lippel, K., Fortin, É., Delisle, A., St-Vincent, Funes, A., Duguay, P., Vézina, S., Prud'homme, P.: Summary Report: Québec Survey on Working and Employment Conditions and Occupational Health and Safety (EQCOTESST). IRSST, Montréal (2011)
6. Clemes, S.A., Haslam, C.O., Haslam, R.A.: What constitutes effective manual handling training?: a systematic review. Occupational Medecine **60**, 101–107 (2009)
7. Verbeek, J.H., Martimo, K.P., Karppinen, J., Kuijer, P.P.F.M., Viikari-Juntura, E., Takala, E.P.: Manual Material Handling Advice and Assistive Devices for Preventing and Treating Back Pain in Workers (Review). Wiley, New York (2011)
8. Hogan, D.A.M., Greiner, B.A., O'Sullivan, L.: The effect of manual handling training on achieving training transfer, employee's behaviour change and subsequent reduction of work-related musculoskeletal disorders: a systematic review. Ergonomics **57**(1), 93–107 (2014)
9. Denis, D., Gonella, M., Comeau, M., Lauzier, M.: Pour quelles raisons la formation aux techniques sécuritaires de manutention ne fonctionne-t-elle pas? Revue critique de la littérature. Essai d'explication et pistes de recommandation pour en améliorer l'efficacité (forthcoming)
10. Denis, D., Lortie, M., St-Vincent, M., Gonella, M., Plamondon, A., Delisle, A., Tardif, J.: Participatory Training in Manual Handling: Theoretical Foundations and Proposed Approach. IRSST, Montréal (2013)
11. Denis, D., St-Vincent, M., Gonella, M., Couturier, F., Trudeau, R.: Analyse des stratégies de manutention chez des éboueurs au Québec - Pistes de réflexions pour une formation à la manutention plus adaptée, Montréal (2007)
12. Denis, D., St-Vincent, M., Lortie, M., Gonella, M., Dion, M.H.: Analyse des activités de manutention de journaliers d'une grande municipalité québécoise: un outil pour composer avec le caractère changeant de la manutention. IRSST, Montréal (2011)
13. Denis, D., St-Vincent, M., Trudeau, R., Imbeau, D.: Stock management influence on manual materials handling in two warehouse superstores. Int. J. Ind. Ergon. **36**(3), 191–201 (2006)
14. St-Vincent, M., Denis, D., Imbeau, D., Trudeau, R.: Symptoms of stress related to the characteristics of customer service in warehouse superstore. Int. J. Ind. Ergon. **36**(4), 313–321 (2006)
15. Denis, D., Plamondon, A., St-Vincent, M., Gonella, M., Lortie, M.: Principles that organize the movement when handling loads: for understanding the techniques used by handlers in real situations (poster). In: Eight International Conference on Prevention of Work-Related Musculoskeletal Disorders/PREMUS (2013)
16. Denis, D., Lortie, M., Plamondon, A., St-Vincent, M., Gonella, M.: IRSST group: proposition d'une définition de la compétence en manutention et impacts sur la formation. Le Travail Humain **76**(2), 129–153 (2013)
17. St-Vincent, M., Vézina, N., Bellemare, M., Denis, D., Ledoux, É., Imbeau, D.: Ergonomic Intervention. Édition MultiMondes (2014)

Intuitionistic Fuzzy REBA Method and Its Application in a Manufacturing Company

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Abstract. Work-related musculoskeletal disorders (WMSDs) are a major health problem. Many methods have been developed for assessing the risk level of work for WMSDs. Rapid Entire Body Assessment (REBA) method is one of the most commonly used observational tools for analyzing working postures and evaluating the risk levels of work. In the conventional REBA method, the angles, optional motions, load/force, load grip and activity states of the work postures are determined according to the scores by the experts. Uncertainty arises, if the experts do not have sufficient experience, they cannot determine the angular and other characteristics of the working postures certainly and subjective opinions exist in the assessment process. These uncertainties can be handled using fuzzy numbers. In this study, Intuitionistic Fuzzy REBA method has been developed to assess the risk of a working posture in a manufacturing company. Then, ergonomic improvements are addressed to minimize the risk.

Keywords: Intuitionistic fuzzy · Manufacturing company · REBA method
Working postures · Work-related musculoskeletal disorders

1 Introduction

Work-related musculoskeletal disorders (WMSDs) are an important health problem for people and companies. WMSDs are defined as an occupational illness by International Labour Organization (ILO) [1]. WMSDs have a multifactorial etiology [2]. The primarily risk factors of WMSDs are repetition, awkward postures, forceful exertions, static postures, continuity and poor work environment [3]. If these risk factors exist in working environments, the occurrence of the WMSDs among workers becomes inevitable.

Each year millions of workers working in different sectors suffer from WMSDs. WMSDs impact not only workers but also their families, employers and society [4]. They result in great amount of costs and loss of time as well [4, 5]. Therefore, it is necessary to identify the risks that may lead to WMSDs by carrying out risk assessments and to implement ergonomic solutions in the workplace to prevent or decrease the adverse effects of WMSDs.

The furniture manufacturing is a process that human resource is used intensively and material handling tasks such as loading-unloading and lifting-lowering materials to machines are performed frequently [6]. Hence, the prevalence of WMSDs is also high in furniture industry.

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In this study, the ergonomic risk assessment of a working posture is conducted in a furniture manufacturing company. Then, ergonomic improvements are recommended to reduce the risk that contributes to the occurrence of WMSDs.

2 Rapid Entire Body Assessment (REBA) Method

Many ergonomic risk assessment methods are used to determine and evaluate the risk exposure of workers related to WMSDs in literature. REBA method developed by Hignett and McAtamney [7] is one of the most widely used observational risk assessment tools for analyzing working positions and identifying risk levels of tasks performed since it measures the ergonomic risks considering whole parts of the musculoskeletal systems. REBA final score in the REBA method varies from 1 and 15 point(s) according to extension and flexion motions in defined body regions, exposures of the load/force, the load grip and activity characteristics during a working position [7].

Whole worker body parts are divided into two body segment groups A and B in the REBA method. Group A includes trunk, neck and legs and Group B contains upper arms, lower arms and wrists. The scores of body regions in groups A and B are calculated separately by utilizing from relevant tables for group A and B. The load/force score is added to the group A score to obtain score A and the load grip score is added to group B score to get score B. The C score consisting of the combination of the score A and B is calculated using the relevant table for score C in the REBA method. The C score and activity scores are then added together to calculate the REBA final score [7].

In the REBA method, the angles, optional motions, load/force, load grip and activity states of the work postures are determined according to the scores by the experts who perform the assessment. These scores are adequately described according to the working posture of the worker. However, the descriptions involve the subjective evaluations of the experts, so they differ with respect to the perception of the experts. Besides, the descriptions for the scores of load/force and load grip contains linguistic terms and different values of the parameters take the same risk score into account in this method. Moreover, if the experts do not have sufficient experience and knowledge and they cannot determine the angular and other characteristics of the working postures certainly, uncertainty arises in the assessment process. In this uncertainty environment, it is difficult to evaluate the risks of WMSDs associated with the working positions utilizing methods that use crisp scores. Hence, it would be more accurate to define a range for the given crisp score to handle the uncertainty. Fuzzy numbers/scores are defined in a range and they are used to measure and model the uncertainties [8].

The aim of this study is to conduct the ergonomic risk assessment by considering working postures and work characteristics under uncertainty to determine the risk levels for WMSDs in a furniture manufacturing company. Therefore, an approach based on intuitionistic fuzzy set theory called Intuitionistic Fuzzy REBA has been developed to assess the risks of working postures in this study.

3 Methodology

3.1 Fuzzy Set

The fuzzy set theory was developed by Zadeh [8] as an alternative to the probability theory in order to model uncertainty. In conventional set theory, an element of a set belongs to a set or not. However, in fuzzy set theory, an element with different membership degrees may belongs to more than one set in the interval [0–1] [8]. In this respect, the fuzzy set theory is more flexible than the classical one.

A fuzzy set A derived from a non-empty set X is represented as [8]

$$\tilde{A} = \{(\mathrm{x}, \mu_{\tilde{A}}(\mathrm{x})) : x \in X\}. \tag{1}$$

where the function:

$$\mu_{\tilde{A}}(\mathrm{x}) : \mathrm{X} \to [0, 1] \tag{2}$$

indicates the degree of membership of the element $x \in X$. The values in the fuzzy set A are fuzzy numbers defined in a range.

3.2 Intuitionistic Fuzzy Sets

Defining an imprecise concept by using a conventional fuzzy set which is also called Type-1 fuzzy set is difficult if available information is insufficient [9]. Atanassov [10] proposed intuitionistic fuzzy set theory as an alternative approach to solve this problem. The intuitionistic fuzzy set theory is a generalized version of the fuzzy set theory and is defined by two functions that express the degree of membership and non-membership of an element to a fuzzy set.

The concepts of intuitionistic fuzzy sets are defined by Atanassov [10, 11] and given in following definitions.

Definition 1. An intuitionistic fuzzy set A derived from universal set X is represented as [10, 11]

$$\tilde{A} = \left\{\left\langle x, \mu_{\tilde{A}}(\mathrm{x}), v_{\tilde{A}}(x)\right\rangle : x \in X\right\} \tag{3}$$

where the functions:

$$\mu_{\tilde{A}}(x) : \mathrm{X} \to [0, 1], \tag{4}$$

$$v_{\tilde{A}}(x) : \mathrm{X} \to [0, 1] \tag{5}$$

and these functions satisfy the following condition:

$$0 \leq \mu_{\tilde{A}}(\mathrm{x}) + v_{\tilde{A}}(x) \leq 1 \tag{6}$$

for each $x \in X$. $\mu_{\tilde{A}}(x)$ and $v_{\tilde{A}}(x)$ are called a membership and non-membership degree of the element $x \in X$, respectively.

Definition 2. The degree of indeterminacy membership of an element x in an intuitionistic fuzzy set A [10, 11]

$$\pi_{\tilde{A}}(\mathrm{x}) = 1 - \mu_{\tilde{A}}(\mathrm{x}) - v_{\tilde{A}}(x). \tag{7}$$

$\pi_{\tilde{A}}(\mathrm{x})$ represents the indeterminacy degree in case where available information is insufficient regarding whether x belongs to intuitionistic fuzzy set A or not.

In this study, triangular intuitionistic fuzzy numbers (TIFNs) are used; therefore, the functions and addition operation related to TIFNs required for this study are described below.

Definition 3. A TIFN is a fuzzy set on R with the form

$$\tilde{A} = \left\langle [\underline{a_1}, \underline{a_2}, \underline{a_3}; \mu_{\tilde{A}}(\mathrm{x})], [\overline{a_1}, \overline{a_2}, \overline{a_3}; v_{\tilde{A}}(x)] \right\rangle \tag{8}$$

where $\underline{a_1}, \underline{a_2}, \underline{a_3}$, $\overline{a_1}$, $\overline{a_2}$, $\overline{a_3}$ are the reference points of the intuitionistic fuzzy number [10, 11].

When the reference values $\underline{a_1}$ and $\underline{a_3}$ in the membership function of the intuitionistic triangular fuzzy number and the reference values $\overline{a_1}$ and $\overline{a_3}$ in the non-membership function are equal to each other, respectively, the intuitionistic fuzzy number is shown as

$$\tilde{A} = \left\langle \overline{a_1}, \overline{a_2}, \overline{a_3}; \mu_{\tilde{A}}(\mathrm{x}), v_{\tilde{A}}(x)] \right\rangle \tag{9}$$

[12].

Definition 4. The membership $\mu_{\tilde{A}}(\mathrm{x})$ and non-membership $v_{\tilde{A}}(x)$ functions of a TIFN are defined as follows [10, 11]:

$$\mu_{\tilde{A}}(\mathrm{x}) = \begin{cases} \frac{x - \underline{a_1}}{\underline{a_2} - \underline{a_1}} \mu_{\tilde{A}}(\mathrm{x}), & \underline{a_1} \le x < \underline{a_2} \\ \frac{\underline{a_3} - x}{\underline{a_3} - \underline{a_2}} \mu_{\tilde{A}}(\mathrm{x}), & \underline{a_2} \le x < \underline{a_3} \\ 0, & otherwise \end{cases} \tag{10}$$

$$v_{\tilde{A}}(x) = \begin{cases} \frac{(x - \overline{a_1})}{\underline{a_2} - \overline{a_1}} v_{\tilde{A}}(x), & \overline{a_1} \le x < \overline{a_2} \\ \frac{(\overline{a_3} - x)}{\underline{a_3} - \underline{a_2}} v_{\tilde{A}}(x), & \overline{a_2} \le x < \overline{a_3} \\ 1, & otherwise \end{cases} \tag{11}$$

where $\underline{a_1} \le \underline{a_2} \le \underline{a_3}$, $\overline{a_1} \le \overline{a_2} \le \overline{a_3}$, $\overline{a_1} \le \underline{a_1}$, $\overline{a_2} \le \underline{a_2}$ and $\overline{a_3} \le \underline{a_3}$.

Definition 5. The addition operation of two TIFNs is defined as follows [10, 11]:

$$\tilde{A}+\tilde{B}=\left\langle[\underline{a_1},\underline{a_2},\underline{a_3};\mu_{\tilde{A}}(x)],[\overline{a_1},\overline{a_2},\overline{a_3};v_{\tilde{A}}(x)]\right\rangle+\left\langle[\underline{b_1},\underline{b_2},\underline{b_3};\mu_{\tilde{B}}(x)],[\overline{b_1},\overline{b_2},\overline{b_3};v_{\tilde{B}}(x)]\right\rangle$$
$$=\left\{\begin{array}{c}\left\langle(\underline{a_1}+\underline{b_1},\underline{a_2}+\underline{b_2},\underline{a_3}+\underline{b_3}),(\overline{a_1}+\overline{b_1},\overline{a_2}+\overline{b_2},\overline{a_3}+\overline{b_3})\right\rangle;\\ \min(\mu_{\tilde{A}}(x),\mu_{\tilde{B}}(x)),\max(v_{\tilde{A}}(x),v_{\tilde{B}}(x))\end{array}\right\} \quad (12)$$

3.3 Intuitionistic Fuzzy REBA Method

Hignett and McAtamney [7] explained the calculation steps of the conventional REBA method, its parameters including the angular and optional postures of the body segments, load/force, load grip and activity states and related score tables comprehensively.

In literature, Type-1 fuzzy sets are integrated with conventional REBA method. Can et al. [13] proposed triangular fuzzy numbers and defined the angles of working postures as fuzzy. Furthermore, Erginel and Toptancı [14] developed two different calculation methodology for Fuzzy REBA method with trapezoidal fuzzy numbers. In the first methodology, all parameters in conventional REBA method are defined as fuzzy numbers and the angles of postures and optional motions are only considered as fuzzy numbers in the second one. In this study, an alternative approach called Intuitionistic Fuzzy REBA has been developed to overcome the problem of uncertainty which occurs in determining the scores of REBA parameters.

All the parameters of the REBA are defined as TIFNs with membership degree and non-membership degree and the reference values for membership and non-membership functions are taken equal in this study. The triangular fuzzy numbers proposed by Can et al. [13] are used as the reference values of triangular intuitionistic fuzzy scores (TIFSs) in this study. The degrees of membership, non-membership and indeterminacy are obtained based on observations and experience of experts who are responsible for the ergonomic risk assessment. Table 1 shows the conventional REBA scores (CRSs), type-1 fuzzy scores (FSs) and reference values of TIFSs.

Table 1. CRSs, type-1 FSs and the reference values for TIFSs.

CRS	1	2	3	4	5	6	7	8	9	10	11	12
FS	$\tilde{1}$	$\tilde{2}$	$\tilde{3}$	$\tilde{4}$	$\tilde{5}$	$\tilde{6}$	$\tilde{7}$	$\tilde{8}$	$\tilde{9}$	$\widetilde{10}$	$\widetilde{11}$	$\widetilde{12}$
Reference values of TIFS	(1, 1, 2)	(1, 2, 3)	(2, 3, 4)	(3, 4, 5)	(4, 5, 6)	(5, 6, 7)	(6, 7, 8)	(7, 8, 9)	(8, 9, 10)	(9, 10, 11)	(10, 11, 12)	(11, 12, 12)

Same calculation steps defined in conventional REBA are used to obtain the intuitionistic fuzzy REBA final score. TIFSs are added by means of Eq. (12).

The methodology of intuitionistic fuzzy REBA method can be explained in following steps:

Step 1: Calculating the intuitionistic fuzzy group A and B scores considering body segment sections.
Step 2: Obtaining intuitionistic fuzzy A score by adding intuitionistic fuzzy group A and load/force scores.

Step 3: Obtaining intuitionistic fuzzy B score by adding intuitionistic fuzzy group B and load grip scores.
Step 4: Determining intuitionistic fuzzy C score from intuitionistic fuzzy A and B scores.
Step 5: Determining intuitionistic fuzzy REBA final score by adding intuitionistic fuzzy C and activity scores.

3.4 Transforming Intuitionistic Fuzzy REBA Scores into Type-1 Fuzzy Scores

In this section, a calculation methodology developed for Intuitionistic Fuzzy REBA method is described with an example. When the results of the addition operations of TIFs are not defined in Table 1, this technique which calculates areas by considering the heights of the membership and non-membership functions can be used. The aim of this technique is to convert Intuitionistic Fuzzy REBA scores to Type-1 Fuzzy scores.

If

$$\tilde{A} = \langle [1, 1, 2\,;\, 0.75, 0.20] \rangle$$

and

$$\tilde{B} = \langle [1, 2, 3\,;\, 0.35, 0.60] \rangle$$

then,

$$\tilde{A} + \tilde{B} = \langle [2, 3, 5\,;\, 0.35, 0.60] \rangle$$

Since the result is not within the defined TIFSs, a type-1 fuzzy score that represents this TIFS is selected. To determine this type-1 fuzzy score, area of TIFS under each fuzzy score is calculated and the average of the area values of the membership and non-membership functions of each fuzzy score is taken. Then, the score which has the largest average area value is selected. Figures 1 and 2 shows the TIFS's areas under type-1 fuzzy scores for membership and non-membership functions, respectively.

The area of TIFS under membership and non-membership functions of $\tilde{3}$ is 0.498 and 0.475, respectively. Besides, the area of TIFS under membership function of $\tilde{4}$ is 0.298 and non-membership function of $\tilde{4}$ is 0.33. The average area value for $\tilde{3}$ is 0.486 and for $\tilde{4}$ is 0.314. As a result, since $\tilde{3}$ as a type-1 fuzzy score has the largest average area, it is selected to represent the result of TIFS.

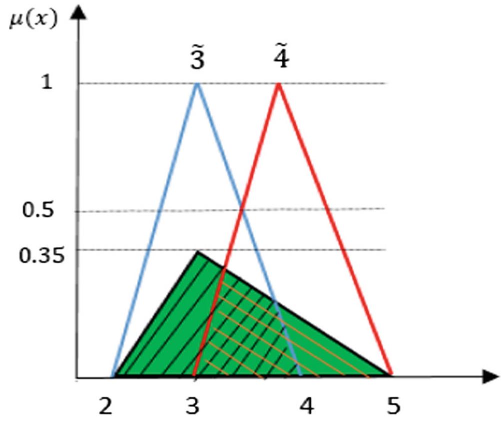

Fig. 1. The area of TIFS under membership functions of type-1 fuzzy scores

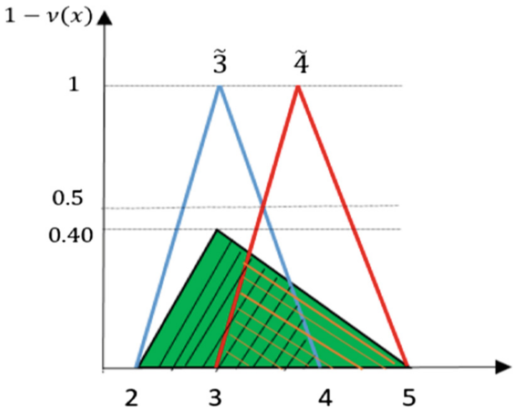

Fig. 2. The area of TIFS under non-membership functions of type-1 fuzzy scores

4 Application

This study was conducted in a wooden furniture manufacturing company in Ankara, Turkey. In this study, the risk assessment of one working posture from sixty-three posture photographs taken at different workstations is explained comprehensively. To show how uncertainty issues result from lack of information, taking same risk scores into account for different values of the REBA parameters, observations, experiences and subjective judgements of the experts in the field of ergonomics can be handled, the working posture is assessed by using Intuitionistic Fuzzy REBA method in this study.

The task of placing the stacked materials to the hole machine is analyzed in this study. As it can be seen in Fig. 3, the task consists of lifting the stacked materials and putting them in the hole machine. The worker works below the waist level that increases the risk of WMSDs while performing the task. Table 2 shows the results of Intuitionistic Fuzzy REBA for this task.

Fig. 3. Placing the stacked materials to the hole machine

Table 2. Intuitionistic Fuzzy REBA final score for the task of placing the materials to the hole machine

Int. Fuzzy A Score					
Int. Fuzzy Neck Score	Int.Fuzzy Trunck Score	Int. Fuzzy Leg Score	Int.Fuzzy Group A Score	Int. Fuzzy Load/Force Score	**Int. Fuzzy A Score**
[1,1,2;0.75,0.20]	[3,4,5; 0.50,0.45] + [1,1,2; 0.75,0.20] = [4,5,7; 0.50,0.45]	[1,1,2;0.90,0.10]	$\tilde{4}$	[1,1,2;0.10,0.90]	$\tilde{5}$
Int. Fuzzy B Score					
Int. Fuzzy Upper Arm Score	Int. Fuzzy Lower Arm Score	Int. Fuzzy Wrist Score	Int. Fuzzy Group B Score	Int. Fuzzy Load Grip Score	**Int. Fuzzy B Score**
[1,1,2;0.90,0.10]	[1,1,2;0.50,0.45]	[2,3,5;0.10,0.90]	$\tilde{2}$	[1,1,2;0.50,0.45]	$\tilde{3}$
Int. Fuzzy C Score	+	Int.Fuzzy Activity Score	=	**Int.Fuzzy REBA Final Score**	
$\tilde{4}$		[1,1,2;0.90,0.10]+ [1,1,2;0.10,0.90]= [2,2,4;0.10,0.90]		$\tilde{7}$	

According to the result of the Intuitionistic Fuzzy REBA method, the level of risk for the task shown is medium. Therefore, ergonomic corrective actions are necessary to eliminate the occurrence risk of WMSDs. The height and position of the platform that the stacked materials are placed should be adjustable in accordance with the body dimension of the workers and ergonomic anti-fatigue mats can be placed on the working floor to avoid the risk effects.

5 Conclusion

In this study, Intuitionistic Fuzzy REBA method is applied for one working posture as an example to show how the uncertainty issues can be handled when conducting the ergonomic risk assessment. All parameters of the conventional REBA method are described as intuitionistic fuzzy numbers in this study. According to the result, ergonomic improvements are suggested for the working posture. Future studies can be done by taking experts' decisions into account separately and combine these decisions regarding scores of parameters using aggregation operators on triangular intuitionistic fuzzy numbers to get more accurate results. Moreover, other fuzzy set theory can be integrated with the conventional REBA or other ergonomic risk assessment tools.

References

1. ILO List of Occupational Diseases. http://www.ilo.org/wcmsp5/groups/public/@ed_protect/@protrav/@safework/documents/publication/wcms_125137.pdf. Accessed 20 Feb 2018
2. David, G.C.: Ergonomic methods for assessing exposure to risk factors for work-related musculoskeletal disorders. Occup. Med. **55**, 190–199 (2005)
3. NIOSH: Musculoskeletal Disorders and Workplace Factors. NIOSH Publication No. 97-141. http://www.cdc.gov/niosh/docs/97-141
4. Boden, L.I., Biddle, E.A., Spieler, E.A.: Social and economic impacts of workplace illness and injury: current and future directions for research. Am. J. Ind. Med. **40**, 398–402 (2001)
5. Goetsch, D.L.: Occupational Safety and Health for Technologists, Engineers, and Managers, 6th edn. Pearson Prentice Hall, Upper Saddle River (2008)
6. Koc, S., Testik, O.M.: Investigation and minimization of musculoskeletal risks in furniture industry with different methods. J. Ind. Eng. **27**, 2–27 (2016)
7. Hignett, S., McAtamney, L.: Rapid Entire Body Assessment (REBA). App. Ergon. **31**, 201–205 (2000)
8. Zadeh, L.A.: Fuzzy Sets. Inf. Control **8**, 338–353 (1965)
9. Li, D.F.: Multiattribute decision making models and methods using intuitionistic fuzzy sets. J. Comput. Syst. Sci. **70**, 73–85 (2005)
10. Atanassov, K.T.: Intuitionistic fuzzy sets. Fuzzy Set Syst. **20**, 87–96 (1986)
11. Atanassov, K.T.: Intuitionistic Fuzzy Sets Theory and Applications. Springer, Heidelberg (1999)
12. Varghese, A., Kuriakose, S.: Centroid of an intuitionistic fuzzy number. Notes Intuitionistic Fuzzy Sets **18**, 19–24 (2012)
13. Can, G.F., Atalay, K.D., Eraslan, E.: Working posture analysis in fuzzy environment and ergonomic workstation design recommendations. J. Fac. Eng. Arch. Gazi Univ. **30**, 451–460 (2015)
14. Erginel, N., Toptancı, Ş.: The ergonomic risk assessment with fuzzy REBA in a furniture manufacturing factory. Çukurova Univ. J. Health Sci. **34**, 19–20 (2017)

Optimizing the Workstation of a Dentist

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Abstract. This study is concerned with optimizing a working postures of a female dentist aged 51, with 20 years of experience. The investigation was performed based on interaction in ergonomics and each layer was assessed by using the most appropriate methods. The user was assessed through Body Part Discomfort, task analysis, time analysis, and RULA. Also the instruments, work place and physical environment were assessed. Data were collected through observation, interviews and questionnaire. The problems were then diagnosed; correspondingly, relevant solutions were suggested. With regard to the available facilities, a number of modifications were applied. Then reassessment took place and the results of assessment and reassessment were compared. As expected, the results revealed that, the working posture of dentist had been well optimized following the modifications, which led to significant reduction in the user's exhaustion and musculoskeletal problem. The efficiency and working satisfaction of the dentist also surprisingly increased.

Keywords: Workstation · Musculoskeletal · HTA · RULA

1 Introduction

Nowadays majority of people are working in professional fields. Based on the latest statistics, specialists of different fields spend eight hours on average at work and most of them are reported to suffer from musculoskeletal injuries [1]. Musculoskeletal Injuries (MSIs), also known as Musculoskeletal Disorders (**MSDs**), are injuries that affect muscles, tendons and ligaments, nerves, blood vessels or related soft tissue. These injuries can occur from overexertion, or from repeatedly using the same muscles over and over again as is the case with Repetitive Strain Injuries (**RSIs**). The Occupational Health & Safety Regulations require employers to identify and assess workplace risk factors in order to eliminate or if that is not practical, minimize, the risk of MSI to workers [2].

As the latest figures show, mental and physical problems resulting from inappropriate working postures are rising, which consequently ends in job dissatisfaction, decreasing efficiency, soaring medical cost and eventually low life quality [3]. This indicates how important it is to consider workstations and optimize them.

In this regard, a myriad number of papers have been recently published to show the importance of the working postures and workstation design in developed countries [4]. These publications have, per se, led to the improvement and extension of this specialty so

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that work and work situation be adaptable with the physical characteristics of the majority of the population. Therefore it can be said that, increasing the work efficiency and decreasing physical as well as mental injuries of the users is the core of optimizing workstations. As the recent studies show, working posts of professions such as working in production agriculture [5], carpeting [3], computer related jobs [6], dentistry [7], and alike are among those jobs which cause the most musculoskeletal injuries. Therefore, there is an urgent need to conduct studies on at least one of these jobs. Since not much has been done on the workstation of dentistry, this study has been carried out on this workstation.

2 Methods and Procedures

In order to optimize a dentistry station, there is a need to investigate the workstation from different perspectives and find out the shortcomings, which may lead to musculoskeletal problems. For this aim, a precise study was performed. All the layers which were introduced as *interaction in ergonomics* by McCormick [8] were investigated and are shown in Fig. 1.

Fig. 1. Interaction in ergonomics

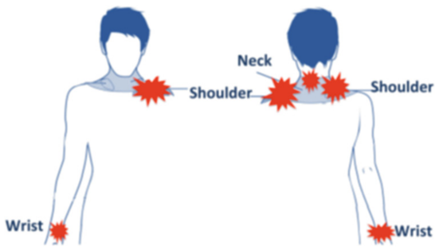

Fig. 2. Body map

2.1 The Dentist

Analyses began from the focal point of the model (**people**). In this regard, the dentist was interviewed and also a relevant questionnaire was given to her in order to find out some information about her age, work experience and musculoskeletal problems. The organs more exposed to damage were identified through Body Map (Fig. 2). For a more thorough investigation, the relation between working hours and pain level was taken into account by using Body Part Discomfort method. The BPD was made, which is shown in Fig. 3.

Due to the result of the interview, questionnaire and the body map, it was found out that, the dentist in this study is a 51 year old lady who has been in practice for 20 years. She does professional work that is routinely performed in a static position. She works eight hours per day, including 3.5 h in the morning and 4.5 h in the afternoon.

She takes a rest break of 10 min after each hour of working. In order to prevent the musculoskeletal problems, she pays attention to physical exercise and plays professional tennis and goes swimming, which boosts her muscle strength and reduces her pain sensation. Whenever she quits her physical activities for a week, her neck, shoulders, and wrists feel achy. According to Fig. 3, the user has felt less pain in her organs during her first few working hours. She, therefore, had not changed her posture and had not seen it necessary to take a rest. Pain in the joints has been worse toward the end of her working day when the mental stress makes her pain even worse. Since she had previously suffered from joint and muscle pain, following a physiotherapist's prescription, she has gone through 20 sessions of physiotherapy. However, she is quite worried about the return of musculoskeletal pain. That's why she shows very good interest in the modifications to be applied on her workstation.

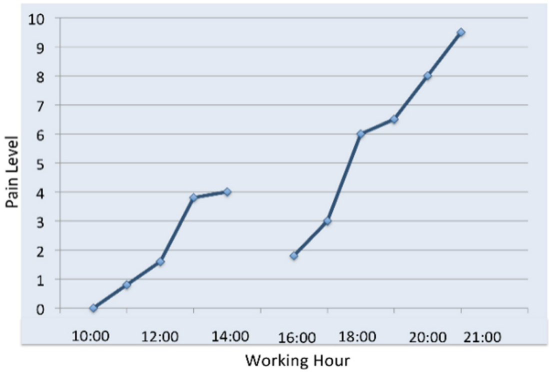

Fig. 3. Body part discomfort graph

2.2 Task

In any working field, tasks and activities determine the body posture. Therefore, in order to prevent inappropriate body postures, the tasks and activities must be investigated carefully. As the focus of the present study is on the workstation of a dentist, her tasks and time spent on them were fully analyzed by HTA[1] method and time analysis. Her postures were assessed through RULA[2] method [9].

Hierarchal Task Analysis: In order to perform task analyses, the task was divided in to five subtasks, which includes Chair adjustment, Light adjustment, Practice, Tool adjustment and Use of tools (Fig. 4).

[1] Hierarchal Task Analysis.

[2] Rapid Upper Limbs Assessment.

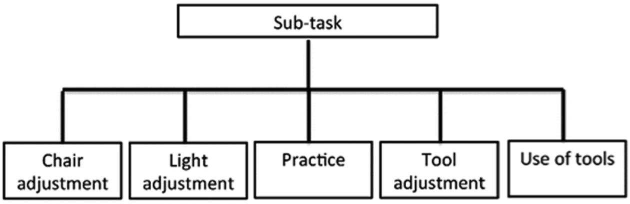

Fig. 4. Hierarchal task analysis

Right after the patient is seated on the unit, the dentist begins to adjust the height and back angle of the unit to have full control over the patient. For these adjustments, she uses some keys located next to the hand piece's tray. To get enough light for dental procedures, the dentist adjusts the height and the angle of the lamp on the unit, and then she uses the dental mirror and probe for diagnosis. Having identified the problem, the dentist selects the required instruments with different sizes and functions and attaches them to the electronic hand pieces to perform the dental procedure. Other instruments including vacuum and laser are adjusted by the keys next to the hand pieces tray. Performing dental procedures follow, including irrigate, emptying, filling, etc. that are static activities of short ranged repeated movements (Fig. 5).

Fig. 5. Chair adjustment, light adjustment, practice, tool adjustment, use of tools (left to right)

Time Analyses: As duration of each task is a very important factor in ergonomics and has a direct relationship with the severity of the resultant damage, time analyses was performed and duration of each task during one working day of the dentist was determined. The result is illustrated in Fig. 6. As the result shows, using dental instruments is the most time consuming task, while chair and light adjustment need the shortest time among all sub tasks. Therefore, using dental instruments, as the longest task, has the most effect on the dentist and requires more consideration.

As Fig. 5, illustrates, the dentist usually sits on a chair pushing her back to a small cushion behind her. Due to the sensitivity and delicacy of her work and to have better concentration, she usually bends forward unconsciously using her left arm as a support.

This imposes pressure on her shoulders because in such positions the shoulder moves to a higher position than normal. The dentist uses her right hand to handle and use small delicate hand pieces. The wrist and fingers of the right hand are involved in short repetitive movements. The dentist feels no pain in her back and lower limbs. Her chair and patient's unit are made in a way that the dentist can adjust the height and the back rest angle. This helps both dentist and patient to get appropriate postures. The patient's cooperation with the dentist is also an important factor. For instance, when the patient moves her/ his head, the dentist has to hold it fixed with her hand. This adds an extra pressure on the dentist's muscles. Moreover, patient's behavior causes mental and physical exhaustion of the dentist.

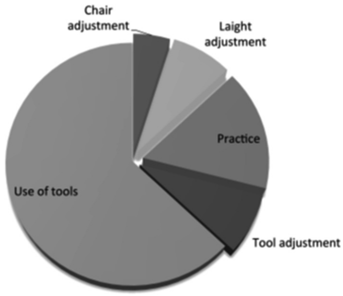

Fig. 6. Time analyses

Rapid Upper Limbs Assessment (RULA): In order to assess the postures and find out the inappropriate ones, there is a need for an assessment. As the dentist works in a seated posture and there is no pressure on her lower limbs, RULA was applied. For this aim each sub task was analyzed. The results are summarized in Table 1.

Table 1. Results of RULA

Sub-task	RULA score	Action level
Chair adjustment	4	3 = Indicates investigation and changes are required soon
	5	
Light adjustment	4	3 = Indicates investigation and changes are required soon
	5	
Practice	5	3 = Indicates investigation and changes are required soon
	5	
Tool adjustment	4	4 = Indicates investigation and changes are required immediately
	7	
Use of tools	7	4 = Indicates investigation and changes are required immediately
	6	

Fig. 7. Tools

As the table reveals, working with hand pieces has the highest score and its action level is 4 which means immediate investigation and changes are needed and correcting modifications must be done as soon as possible to prevent more damage. The lowest scores belong to chair and light adjustment with action level of 3 which means these two sub tasks require investigation and changes soon. The subtasks of practice and tool adjustment need more investigation.

2.3 Equipment and Machines

Equipment and machines can make the work either easy and joyful or hard and boring. The hand pieces (Fig. 7) used by the dentist were, therefore, carefully inspected. The user also added her ideas about their efficiency. The major applied tools are pen like electronic hand pieces that have equal size. Out of all the hand pieces, dental mirrors, probes, turbines, angles and suction are the most applicable. Since they are used by hand, the user's wrist, hand, and fingers are routinely involved. The user has purchased the lightest ones, so it seems that she has no problem using them.

2.4 Work Space

The workspace was divided into two personal and wider work spaces.

Personal Work Space: It is the space within the reach of the user, which includes the unit, the dentist's chair, and the hand pieces' table. The chair and units are height adjustable. The overhead light is also rotatable to all sides. The table turns 360° and its height can be easily adjusted. Consequently, the personal workspace is quite reachable for the dentist.

Wider Work Space: In order to investigate wider workspace, related photos were taken (Fig. 8) and the plan was drawn in Fig. 9.

Fig. 8. Dentists' office

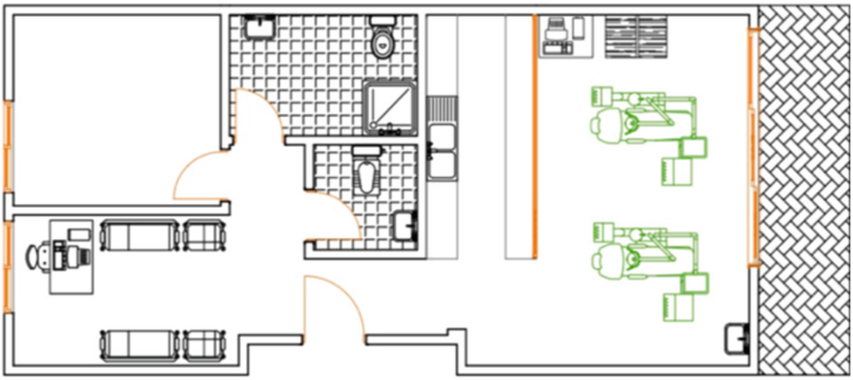

Fig. 9. Plan of dentists' office and waiting room

As shown in plan, there are two dental units, one desk and two portable drawers in the room. As monitor and other tools are located in the other side of the same room, the dentist, therefore, moves away from her chair and walks a short distance. This reduces the pressure on her muscles. There is not enough space for the dentist's assistant to move freely around (Fig. 10). The dentist's office is separated from the waiting room with a noise permeable partition (Fig. 11). The room has no doors, which allows the noise to easily transfer to the dentist's place. The waiting patients' noise adds to the dentist's tension making her even more exhausted. The cramped space next to the dentist' room, which the dentist uses to rest, does not really refresh her (Fig. 12).

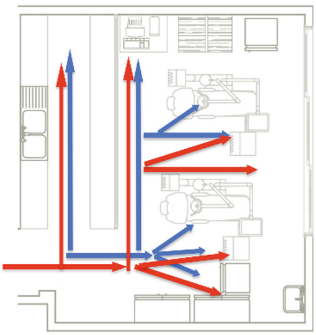

Fig. 10. Dentists'& assistants' circuits

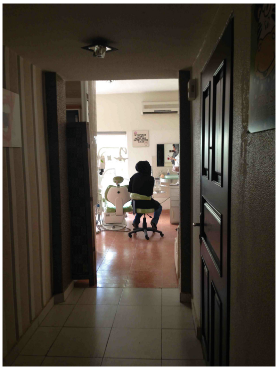

Fig. 11. Dentists' room

Fig. 12. Resting area

2.5 Physical Environment

People work and live in physical environments. Therefore, physical environment have noticeable influence on them. The factors constituting this environment are light, temperature, noise, dust, radiation, etc. Applying modifications in such factors can, definitely, boost the efficiency, increase the production rate, and provide safety and health for the users. In order to reach such efficacy, standards need to be complied. Otherwise, work induced stress level would rise, leading to the user's exhaustion, low efficiency, and musculoskeletal complications. For more accurate investigation of the physical environment, each factor was separately assessed, as follow.

Lighting: The room has both natural and artificial lighting. The natural light is provided through a big window right in front of the patients' unit, which makes no shade on the workspace. The artificial light for the whole place is taken from two florescent bulbs in the ceiling. The unit has a Cialitic light, which gives cool light with no shade. The height and angle of the light is adjustable. The lighting is, therefore, appropriate for the place.

Temperature: The place is equipped with the central system, which keeps the air temperate appropriate in all seasons.

Air Pollution: Due to the geographical location, the level of dust and particles in the room air is quite high. This can be a harmful and needs further consideration.

Noise: All the noise in the room is from the cooling system, dentistry tools, water pomp from outside, the computer, and the patients in the waiting room and the office. The dentist is annoyed with the continual patients' noise and prefers to spend her rest in a quiet place. In such a place, it is not strange that noise pollution brings about boredom and stress.

2.6 Work Organization

In addition to the physical factors mentioned above, the mental status of the dentist is also very important and interrelated with job design and work organization. The mental complications resulted from work organization and job design, could even cause physical injuries. Furthermore, tightness of job market, inappropriate professional behaviors, low income, long working hours, lack of sufficient education, etc. are among factors that pose mental pressure on the users. In the present study, on the basis of the observations and the interviews with the dentist, it was found that she is swept along with too much to do and little time to rest. In spite of having the right experience and knowledge to perform the task, she is still confronted with high stress and work pressure, which is, to a large extent, due to the fact that her job is among those that directly has to do with human lives. However, as she is self-employed, Job security and income are not very stressful for her. Work induced stress, and the required precision and thoroughness to perform delicate tasks, make the dentist stay in an improper body postures. More specifically, the neck is leaned forward and the shoulders are lifted higher than normal. The patient himself can also trigger the stress by avoiding keeping his/her head fixed. In such a case, the dentist has to hold the patient's head to prevent the extra movements. This static muscle pressure and improper posture cause the dentist's neck, joints, and muscles to become achy.

3 Gaps and Solutions

Data gathered so far led to the detection of the problems and their source. First of all, based on the workspace plan, applying slight modifications in the interior design will help optimizing the workstation. Since the drawers block the dentist's moving route, it is suggested to locate the drawers on top of each other (Fig. 13). In addition, no room is specified as the resting space for the dentist. Therefore, part of the balcony can be separated by glass walls to be used for such a purpose (Fig. 14). In order to provide privacy for the dentist, non- transparent glass could be used. Moreover, a resting chair as suggested by the dentist could be used. Therefore a noise free relaxing environment could be provided for her rest breaks.

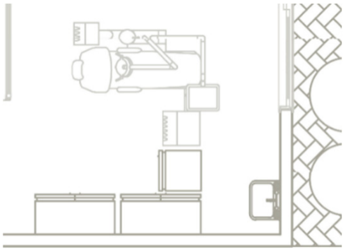

Fig. 13. New location of drawer

Fig. 14. Balcony, which can be used as resting area

As one of the problems that cause lots of stress for the dentist is the noise that comes from waiting room, there is a need for separating these spaces. Substituting a partition with a door, which separates the waiting room from the dentist's office, could separate waiting room and would reduce the noise level in dentist working area. Reducing the noise level and providing more privacy for the dentist would give more concentration and boosts the work efficiency. As further suggestion, playing light music has been reported [10], to contribute to lowering the patient's stress and making the place more tranquil.

Another gap is related to the patient's extra movements, which causes problems for the dentist trying to immobilize the patient's head and chin. To prevent such a problem, a monitor can be implemented in front of the patient. It can keep her/him busy by what is played. As a further suggestion, a headband was designed for fixing the patient head. Such a headband keeps the patient's head immobilized, so the dentist does not have to use her hands for keeping the patient's head. This simple inexpensive headband is made of a webbed spongy piece, which prevents the force imposed to the patient's head. The spongy part and the lace can be adjusted to fit the patient's head size (Fig. 15).

Fig. 15. Designed head band

Fig. 16. Elbow support

As mentioned above, the dentist has to lean forward to get a closer and more accurate look in patient's mouth. In such cases the dentist can use a magnifier, which could be attached to her head. It magnifies the workspace dimensions. Since the dentist also suffers from pain in her left shoulder, adding a separable part as a support for the elbow would reduce the pressure imposed to the dentist's shoulder. This added part is attached to the back of the dentist's chair, and since it is separable and movable, it does not restrict the dentist's hand movement (Fig. 16).

In addition to the above mentioned suggestions including modifications in plan, tools and task, applying simple inexpensive changes in the work schedule could be effective in optimizing the workstation. For instance, the assistant and the secretary can change the work situation to a point that reduces the tension level for the dentist. This could be done by setting appointments in the right time intervals that prevents crowd of the patients and provides some free time for the dentist to rest, as well. In such a case the work place turns out to be more joyful, reducing the crowd induced stress.

Finally, in this part, some solutions have been suggested, out of which three have been operationalized. The rest have remained undone.

4 Reassessment

Once the solutions were suggested, some of them were applied, which include modifications in the interior design, playing light music, designing a headband and applying changes in the work schedule. After applying modifications, the dentist was shadowed for a mount and after that reassessment was performed. For this aim, a questionnaire was given to the dentist and observation and interview were carried out. In addition the posture analyses was performed by RULA method. The results indicated that the user had more comfort. According to the dentist, her mental and physical tiredness were reduced. She felt less pain in her joints and muscles, especially in her neck and left shoulder. Her work was even better scheduled and she enjoyed better interaction with the assistant. It all led to more work satisfaction of hers and she found her work place more joyful and relaxing. The reassessment results are presented in Table 2 and Fig. 17.

Table 2. Result of reassessment by RULA

Sub-task	RULA score	Action level
Chair adjustment	4	3 = Indicates investigation and changes are required soon
	5	
Light adjustment	4	3 = Indicates investigation and changes are required soon
	5	
Practice	5	3 = Indicates investigation and changes are required soon
	5	
Tool adjustment	4	4 = Indicates investigation and changes are required immediately
	7	
Use of tools	5	3 = Indicates investigation and changes are required soon
	6	

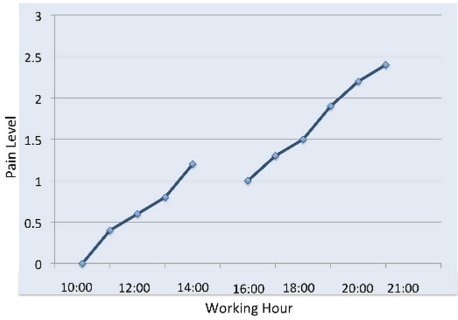

Fig. 17. Body part discomfort graph

5 Discussion

The results shown in RULA table are sorted in a way that the left and right hands are scored separately. As the priority in this research is to either reduce or correct the dangerous postures, the action level of the higher RULA score is involved (Tables 1 and 2). Although the result of reassessment does not show any significant changes as compared to the previous situation, the user has, through her interview, expressed much more satisfaction from the applied changes. This controversy is quite logical because although stress and mental status can trigger physical pain in joints and muscles, they are not included in RULA analysis. Through reduction of some harmful mental factors, the user's physical pain is alleviated. Moreover, in RULA method, factors such as working time duration and static muscle load are not considered. They have been, however, involved in this study and relevant modifications have been applied. Therefore, it is not surprising that although the significant numerical changes could not be observed, the user reports remarkable satisfactory differences in her work place afterwards.

6 Conclusion

Workstations have very important roles to play in peoples' work quality and satisfaction, which in a larger scale, helps making an active prolific society. As the dentist's workstation has direct relationship with peoples' health, it was crucial to be optimized. Such a job necessitates a high level of precision and thoroughness, which imposes a lot of stress. Usually, dentists are so involved in their precision demanding activity that they become ignorant of their own physical health. In this regard, large amount of data has been gathered in this study, the sources of the problems have been identified and relevant suggestions have been given. Modifications were applied and reassessments performed. The results revealed that the dentist's workstation has been optimized and the dentist has expressed more satisfaction from her working post than before. Although the changes have not been numerically significant, they have brought positive changes in the quality of the dentist's life. This means that the present study methods need to be improved. As it can be seen quite simple and inexpensive modifications were made and these applied changes have proved to be very effective in improving the workstations. To sum up, improving the working and living situation has little to do with spending large amount of budget on expensive and complicated solutions. That is, wisely applied, slight simple modifications can bring about fundamental improvements.

References

1. Wearsted, M., Westgaard, R.H.: Working hours as a risk factor in the development of musculoskeletal complaints. Ergonomics **34**(3), 265–276 (1991)
2. Hagberg, M., Silverstein, B., Wells, R., Smith, R., Carayon, P., Hendrick, H.P., Perusse, M., Kuorinka, I., Forcier, L.: Work-related Musculoskeletal Disorders (WMSD): A Handbook for Prevention. Taylor and Francis, London (1995)
3. Choobineh, A., Shahnavaz, H., Lahmi, M.: Major health risk factors in Iranian handwoven carpet industry. JOSE **10**(1), 65–78 (2004)
4. Spielholz, P., Silverstein, B., Morgan, M., Checkoway, H., Kaufman, J.: Comparison of self-report, video observation and direct measurement methods for upper extremity musculoskeletal disorder physical risk factors. Ergonomics **44**(6), 588–613 (2001)
5. Murphy, D.: Safety and Health for Production Agriculture. St. Joseph., ASAE, MO (1992)
6. Balch, A., Coulter, B., Duffner, A., Fackelmann, T., Goggins, R., Hays, J., Joyce, M., Mehring, J., Plott, C., Simonton, K., Tillman, B., Wilder, P.: Practical solutions for a safer workplace. WISHA Services Division Washington State Department of Labor and Industries (2002)
7. Valachi, B., Valachi, K.: Mechanisms leading to musculoskeletal disorders in dentistry. J. Am. Dental Assoc. **134**, 1344–1350 (2003)
8. Cordiner, L., Davies, S., Haines, H., Haslegrave, C., Hide, S., Wilson, J.: A distance learning course on the fundamentals and practice of ergonomics. Ergonomic application in the workplace (1998)
9. McAtamney, L., Corlett, E.N.: RULA: a survey method for the investigation of work-related upper limb disorders. Appl. Ergon. **24**(2), 91–99 (1993)
10. Gaynor, M.: Meditation and Music for Sound Health. Sound Medicine Series (2006)

Biomechanical Risk Assessment of Pathologists in the Morgue

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Abstract. The purpose of this study is to research the risk of biomechanical overload in pathologists during autopsies performed in dissection room. During autopsies, operators are exposed both to the risks of manual handling, in transferring the cadaver from the trolley to the dissection table (and vice versa), and to awkward postures during the incision and opening of the cadaver to examine the organs. Following task analysis, we decided to use, according to the task, the methods that best describes it and include its peculiar characteristics. The methods used were: the REBA protocol, 3DSSPP software and surface electromyography. The results show that, in almost all the tasks investigated and with all the methods used, there was a medium-high risk of biomechanical overload. In the light of these results, we suggest possible intervention strategies for the prevention of musculoskeletal disorders (MSDs) during the performance of autopsies.

Keywords: Dynamic REBA · EMG · Ergonomic · MSDs · Coroner

1 Introduction

Performing autopsies in the dissection room is a job that, despite featuring greatly varied activities of different durations, involves maintaining a standing position and awkward postures of the trunk and upper limbs. These job characteristics can constitute a risk for the musculoskeletal apparatus.

The few studies found in literature [1–3] have mainly investigated the risks for the musculoskeletal apparatus for pathologists in anatomical pathology laboratories, in particular in relation to the postures adopted during the examination of anatomical samples under the microscope.

No study, to date, has described and illustrated the biomechanical risk of operators during autopsy in the dissection room.

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2 Materials and Methods

Despite the fact that every autopsy of a cadaver is different, it was possible to identify the following six tasks that are characteristic of all autopsies, based on videos and interviews with the operators:

1. transferral of the cadaver from the trolley to the dissection table;
2. incision of the scalp;
3. opening the skull using a vibrating autopsy saw;
4. Y incision of the chest and abdomen and separation of the skin and muscle layers;
5. examination of the chest and abdominal cavity and removal of the organs;
6. examination of the removed organs on the dissection table.

2.1 Akward Postures

Based on observation and videos, we performed postural analysis using "dynamic" REBA [4, 5] protocol to assess the tasks from 2 to 6. We sampled one frame every three seconds from recorded videos, then computed the average REBA index.

We used the Kinovea freeware software to assess the objective posture of each body area.

2.2 Manual Handling of Loads

The action of transferring the cadaver from the trolley to the dissection table (Task 1) was assessed using 3D Static Strength Prediction Program (3DSSPP) software v6.0 [6] developed by the University of Michigan. The software calculates the force applied to the L4/L5 lumbar discs, the percentage of the population able to perform the task investigated without suffering damage for each body area (wrist, elbow, shoulder, trunk, hip, knee and ankle) and the stability of the operator.

The 3DSSPP software was used for evaluation during the initial stage of the handling (lifting from the trolley) and the final stage of the handling (lowering onto the dissection table), simulating a handled load of 10, 20 or 30 kg for each operator.

The values obtained were compared with the limit values, divided according to gender and age, as shown in Fig. 1 by Jager [7] and in the Technical Report ISO/TR 12296 [8].

Limits for compressive forces on lumbar discs		
Age	Female	Male
20 years	4.4 kN	6.0 kN
30 years	3.8 kN	5.0 kN
40 years	3.2 kN	4.1 kN
50 years	2.5 kN	3.2 kN
≥ 60 years	1.8 kN	2.3 kN

Fig. 1. The figure shows the limits for forces applied to the lumbar discs, according to gender and age, proposed by Jager in 2001 and in the Technical report ISO/TR 12296.

2.3 Surface Electromyography (sEMG)

Tasks 1 and 3 were also assessed using sEMG:

Electrical muscle activity was recorded using a 16-channel Wi-Fi surface electromyography system (FreeEMG, BTS SpA, Milan, Italy) at a sampling frequency of 1 kHz.

After skin preparation, surface electromyographic signals were detected from each muscle by two Ag/AgCl pregelled disposable surface electrodes (H124SG, Kendall ARBO, Donau, Germany) which had a detection surface of 10 mm (gelled). Electrodes were placed bilaterally over the muscle belly of Erector Spinae (ES), Upper Trapezius (UTRAP) Middle Trapezius (MTRAP) and Anterior Deltoideus (ADELT) in the direction of the muscle fibres, according to the Atlas of Muscle Innervation [9].

In order to elicit the maximal voluntary isometric contraction (MVCi) from each muscle, three isometric exertions were performed, according to the SENIAM guidelines [10].

The sEMG signals were rectified, integrated with a mobile window of 0.125 s, filtered with a 5 Hz Hamming low-pass filter and normalized to the maximum value of the MVCi. The mean activation value for each muscle was then calculated as percentage of MCVi.

3 Results

3.1 Awkward Postures

Posture analysis of Task 2 using the REBA protocol (analysis of 175 frames) recorded average values of 5.1 for the right upper arm and 5.7 for the left upper arm. A peak value of 10 was recorded for both arms for Task 2.

The posture adopted by the operator for performing Task 3 recorded average REBA values (analysis of 118 frames) of 6.5 for the right upper arm and 6.1 for the left upper arm. The peak value for both arms was 11.

Posture analysis of Task 4 (analysis of 35 frames) recorded average REBA values of 6.7 for the right upper arm and 6.1 for the left upper arm, with peak values of 9 for both arms.

Analysis of Task 5 (analysis of 77 frames) gave average REBA values of 7.4 for the right upper arm and 7 for the left upper arm, with peak values of 10 for both arms.

Finally, the average REBA values for Task 6 (312 frames) were 4.3 for the right upper arm and 4.5 for the left upper arm, with peak values of 7 for both arms (Figs. 2 and 3).

Task 3 was also assessed using sEMG. This stage recorded significant activity of the left Anterior Deltoid (Fig. 4), with peaks of between 20% and 30% of MVC, and of the right Upper Trapezius (Fig. 5), with peaks of between 40% and 50% of MVC.

3.2 Manual Handling of Loads

As far as concerns the lifting action in Task 1, in the initial stage, the L4/L5 compression force increased from 2856 N in the simulation using 10 kg to 3762 N with 20 kg and reached 4895 N in the simulation with 30 kg. In the final stage, however, the

Fig. 2. The image shows the operator performing Task 4, i.e. the Y incision of the chest and abdomen and the separation of the muscle layer.

values went from 3063 N in the simulation using 10 kg, to 3846 N with 20 kg and reached 5182 N in the simulation with 30 kg.

Figures 6 and 7 show the analysis using 3DSSPP software and the results obtained for the action of transferring the cadaver from the trolley to the dissection table in the simulation using 30 kg.

In terms of the percentage of the population able to perform the task without suffering damage to the various areas of the body, in the simulation using 30 kg, at the start of lifting, critical values were recorded for the wrist (19%), trunk (22%) and shoulders (29%). In the final stage, the most critical values were again recorded for the trunk (17%), wrist (18%) and shoulders (26%).

Operator balance was optimal only in the handling of 10 kg in both stages of lifting, whereas the operator was unstable in all the other situations.

The sEMG readings were instead taken using the operator who handled the head of the cadaver. sEMG analysis recorded significant activation levels for both Erector Spinae (Fig. 8), in particular on the left, the direction in which the transfer was made, recording peaks of between 60% and 70% of MCV; the right ES was less engaged but the values were still significant, with peaks of between 50% and 60% of MCV.

Fig. 3. The image shows the operator performing Task 3, i.e. the opening of the skull using a vibrating saw.

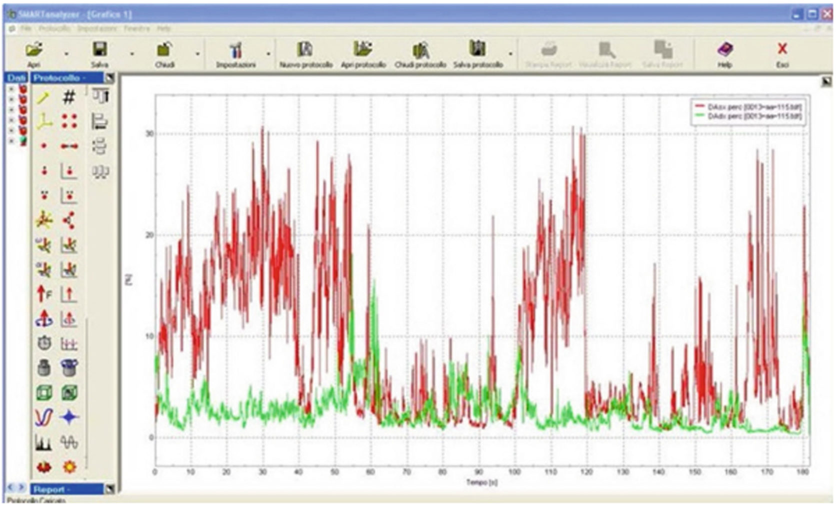

Fig. 4. The image shows the sEMG envelope of the Anterior Deltoids (left in red and right in green) during Task 3. The left Deltoid reaches peak values of between 20% and 30% of MVC. The right AD values are less significant, at around 5% of MVC.

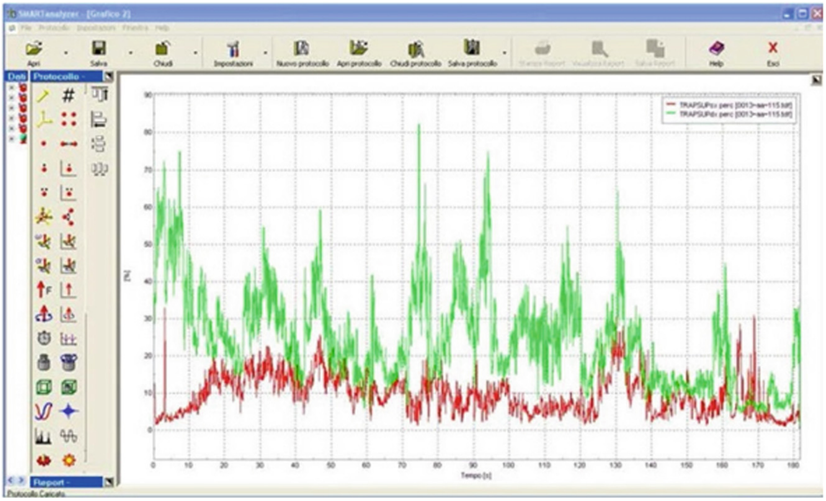

Fig. 5. The image shows the sEMG envelope of the Upper Trapezius (left in red and right in green) during Task 3. The right Trapezius reaches brief peaks of activation of between 40% and 50% of MVC several times. However, the left Trapezius displays values of around 10–20% of MVC.

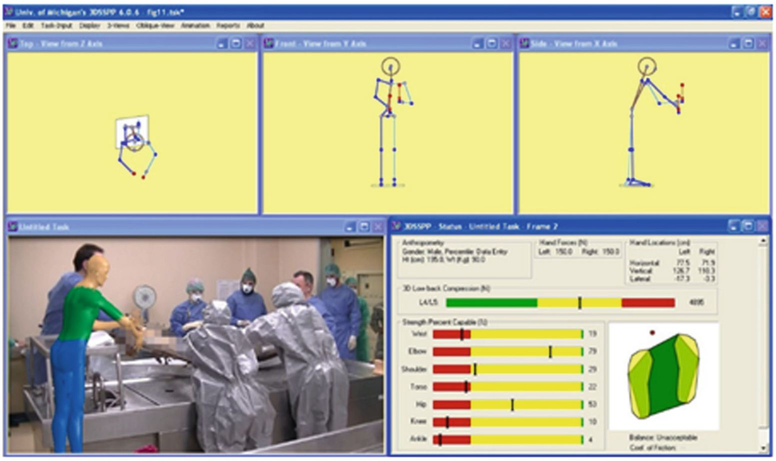

Fig. 6. The image shows the reconstruction using 3DSSPP of the action of transferring the cadaver from the trolley to the dissection table. The results are for the initial stage of the transfer, lifting a hypothetical weight of 30 kg.

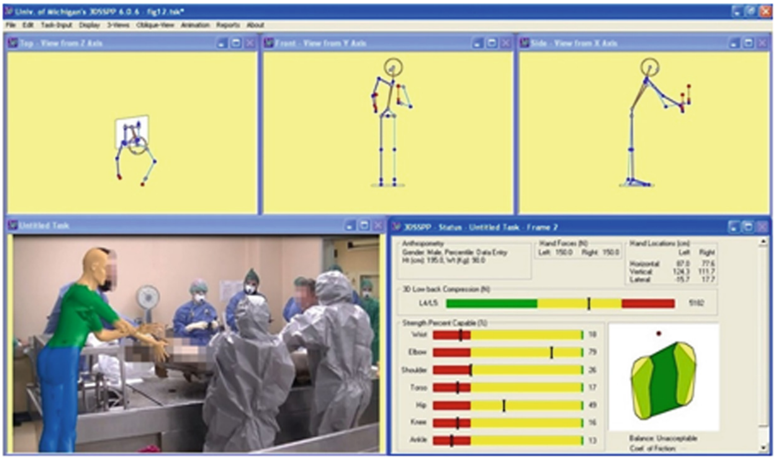

Fig. 7. The image shows the reconstruction using 3DSSPP of the action of transferring the cadaver from the trolley to the dissection table. The results are for the final stage of the transfer, with a hypothetical weight of 30 kg.

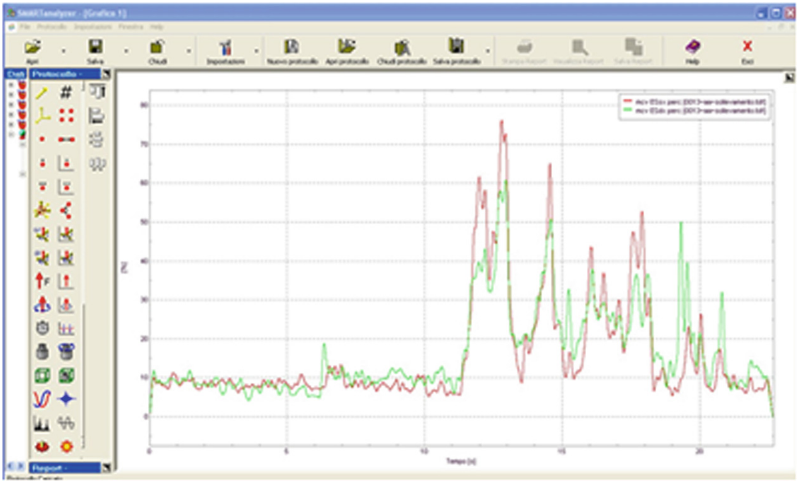

Fig. 8. The image shows the trend of both the ES during the action of transferring the cadaver from the trolley to the dissection table by the operator standing at the head. The red signal represents the left ES and the green signal represents the right ES.

4 Conclusions

The study highlighted the fact that the performance of autopsies involves risks for the musculoskeletal apparatus caused by manual load handling, awkward postures and the characteristics of the instruments used.

Observation allowed us to identify a considerable variation in the activities undertaken and their duration. We also observed a frequent change in the posture of the trunk and upper limbs adopted by the operators, in order to adapt their posture to fit the anthropometric characteristics of the cadaver under autopsy, which different each time.

The results show that, in the postural analysis performed using the dynamic REBA protocol, all the average REBA values obtained fall within the category of medium risk, apart from for the right upper arm in Task 5, which gave an average value of 7.4, just above medium risk.

The peak REBA values for all the tasks fell within the high-risk category, with the exception of Task 6, which fell within the medium risk category. Task 6 gave the lowest risk levels of all the tasks investigated, even for the medium REBA value (4.3 for the right arm and 4.5 for the left arm).

The posture of the trunk, which often displayed high degrees of forward bending, twisting and sideways bending contributed significantly to reaching these levels of risk.

sEMG analysis highlighted the fact that the muscles most used in Task 3 were the left anterior deltoid, which reached activation levels of up to 30% of MCV, and the right upper trapezius, which repeatedly reached peaks of activity of between 40% and 60% of MCV. Analysis of this task did not consider the risks of vibration for two reasons: (1) the difficulty in quantifying the effects of interaction between vibration and posture in the occurrence of musculoskeletal disorders; (2) given that it was a real work situation, we couldn't standardize the task to perform multiple repeatable tests.

As concerns the action of transferring the cadaver from the trolley to the dissection table, the simulations of the operator at the head of the cadaver assuming three different weights, performed using 3DSSPP software, recorded L4/L5 compression forces of between 2886 N and 4895 N in the initial stage of lifting and between 3063 N and 5182 N in the final stage. The highest value recorded of 5182 N is below the limit proposed by Jager (Fig. 1) for healthy males under 30 only. The percentage of the population able to carry out the lifting without suffering damage was very low, according to the 3DSSPP software, especially for the trunk, wrist and shoulders.

The results of the sEMG on the operator handling the head of the cadaver confirm that the action of transferring the cadaver, despite lasting for just a few seconds, involves considerable levels of muscle engagement. Indeed, the electromyography signals for this task recorded activation levels of between 50% and 60% of MCV for the right erector spinae and between 60% and 70% of MCV for the left erector spinae, left being the direction in which the cadaver was lifted.

In the light of these results, it would be useful to study and adopt strategies suitable for the prevention of musculoskeletal disorders that must include:

1. a proper work plan;
2. the choice of suitable instruments and their correct use;
3. research of the best working positions (operator/cadaver position). In particular, there is the need for systems to regulate the height of the dissection table in relation to the task and the anthropometric parameters of the operator;
4. training on correct load handling manoeuvres and correct work postures.

References

1. Fritzsche, F.R., Ramach, C., Soldini, D., Caduff, R., Tinguely, M., Cassoly, E., Moch, H., Stewart, A.: Occupational health risks of pathologists–results from a nationwide online questionnaire in Switzerland. BMC Public Health **12**, 1054 (2012). https://doi.org/10.1186/1471-2458-12-1054
2. Sundaragiri, K.S., Shrivastava, S., Sankhla, B., Bhargava, A.: Ergonomics in an oral pathology laboratory: back to basics in microscopy. J. Oral Maxillofac Pathol. **18**(Suppl 1), S103–S110 (2014). https://doi.org/10.4103/0973-029x.141341
3. Arora, A., Uparkar, S.M.: Ergonomic risk assessment in pathology laboratory technicians. Int. J. Ther. Rehabil. Res. **4**(3), 15–19 (2015)
4. Hignett, S., McAtamney, L.: Rapid Entire Body Assessment (REBA). Appl. Ergon. **31**(2), 201–205 (2000)
5. Hignett, S., Jones, A.: Safe access/egress systems for emergency ambulances. Emerg. Med. J. **24**, 200–205 (2007)
6. Chaffin, D.B., Andersson, G.B.J., Martin, B.J.: Occupational Biomechanics, Chap. 6, 4th edn. Wiley, New York (2006)
7. Jäger M: Load and load-bearing capacity of the lumbar spine in everyday working life—an interdisciplinary approach for ergonomic work design [in German: Belastung und Belastbarkeit der Lendenwirbelsäule im Berufsalltag — ein interdisziplinärer Ansatz für eine ergonomische Arbeitsgestaltung]. Fortschritt-Berichte VDI, Reihe 17, Nr. 208. VDI-Verlag, Düsseldorf (2001)
8. ISO/TR 12296:2012 Ergonomics - Manual handling of people in the healthcare sector
9. Barbero, M., Merletti, R., Rainoldi, A.: Atlas of muscle innervation zones: understanding surface electromyography and its applications. Springer, Heidelberg (2012)
10. Hermens, H.J., Freriks, B., Merletti, R., et al.: European recommendations for surface ElectroMyoGraphy (SENIAM) (2000). Ed CLUT

Job Design and Ergonomic Risk in Administrative Jobs

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Abstract. There are many administrative workers exposed to awkward postures due to poor design of work stations and bad postural habits. We proceeded to evaluate work stations by applying the RULA methodology and the Check List ROSA and it was found that 87.5% of positions needed immediate changes in its design and its occupants more information on postural hygiene. The body segments with the highest postural load are wrists, upper arms, neck and trunk.

It is also necessary that an anthropometric profile of the Ecuadorian population can be developed so that in the future furniture and accessories can be designed according to the dimensions of our users to eliminate the current imbalance and reduce the incidence and prevalence of musculoskeletal disorders.

Keywords: Ergonomic risk · Anthropometry · Postural load

1 Introduction

Administrative work is one of the most frequent activities in the current times, the workers must interact with computer equipment most of their working hours and they depend a lot on them to provide job results. 24% of accounting and administrative workers consider that work affects their health, while 66% think that it doesn´t influence in any way [1].

The working space must be designed according to the anthropometric variables of the users and the work tools located in an appropriate way to provide comfort [5].

The workstations should have the ability to incorporate adjustability to improve the comfort of administrative users [8], but the design is not suitable mainly in relation to the height of the keyboard, position of the monitor and the design of the chair [10]. The location of the work tools such as the monitor plays an important role in the adoption of healthier postures [2], as well as the availability of an ergonomic chair [4].

Users should have access to a program of information and training about ergonomic risks to which they may be exposed during their work performance and so they can have the ability to adjust their work station and avoid bad postural habits. A well-designed and systematically evaluated program demonstrates the positive effects that reduce associated ergonomic problems [7].

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Administrative workers exposed to ergonomic risks can develop in the medium and long term musculoskeletal disorders in different body segments such as the upper extremities, neck and trunk [1].

2 Materials and Methods

Is a descriptive and cross-sectional study, through the application of the RULA (Rapid Upper Limb Assessment) Method and the ROSA (Rapid Office Strain Assessment) checklist that allow us to determine the risk by postural load and the quantification of risks associated with working with computers to establish a level of action to implement preventive and corrective measures.

The RULA Method was developed to determine the level of risk by postural load that can suffer various body segments such as neck, trunk, legs, upper arm, lower arm and wrist, in addition to the influence of factors such as muscle activity and external forces or loads.

It determines four levels of action in relation to the values obtained by means of a system of codification of the different factors, always assigning a value of 1 to the neutral position in the body segments, values that increase progressively while the position evaluated is more asymmetric. The levels of action generate a level of intervention required to reduce the risks of injury due to the physical load on the workers [6].

The ROSA Method was created using postures that were described in the CSA Z412 guidelines for ergonomics in offices and by the Canadian Occupational Safety and Health Center. All the positions that are described as ideal or neutral in the referred standards have a score of 1 that corresponds to the minimum score of each area within the different sections of the methodology. Deviations from the neutral posture are rated progressively higher up to a value of 3. There are certain factors that can be used concurrently with the base risk factors.

The risk factors are grouped into the following groups: chair, monitor, telephone, keyboard and mouse. The final ROSA score greater than 5 is associated with a significant increase in worker discomfort and could indicate a potential increased risk of suffering a musculoskeletal disorder; scores equal to or less than 4 do not determine that there is no associated risk, but the probability of discomfort and injury is lower. The method recommends that scores equal to or greater than 5 require an evaluation and immediate changes [9].

The personnel object of this cross-sectional study performs administrative tasks in the province of Pichincha-Ecuador, exist throughout the province 341.711 administrative workers [3]. The sample obtained with a confidence interval of 90%, a sampling error of 5% and a distribution of answers of 50% are 271 workers. The inclusion criteria for the gathering of information was that the evaluated personnel spend at least 50% of their working hours interacting with a computer.

The positions evaluated were determined using desktop or laptop, each of these was called type positions. The information gathering, and methodological application was carried out in several administrative companies of the city of Quito.

The ROSA ergonomic risk checklist was applied to the sample, while the RULA Method was executed in the two type positions.

3 Results

The results obtained from the application of the ROSA ergonomic risk checklist determined that 34 positions had an acceptable level (score equal to or less than 4) and 237 evaluated positions had an unacceptable level of risk (score equal to or greater than 5).

The percentage of unacceptability corresponds to 87.5% of the positions evaluated and is distributed mainly between the final scores 5 and 6 (58.6%) (Figs. 1 and 2).

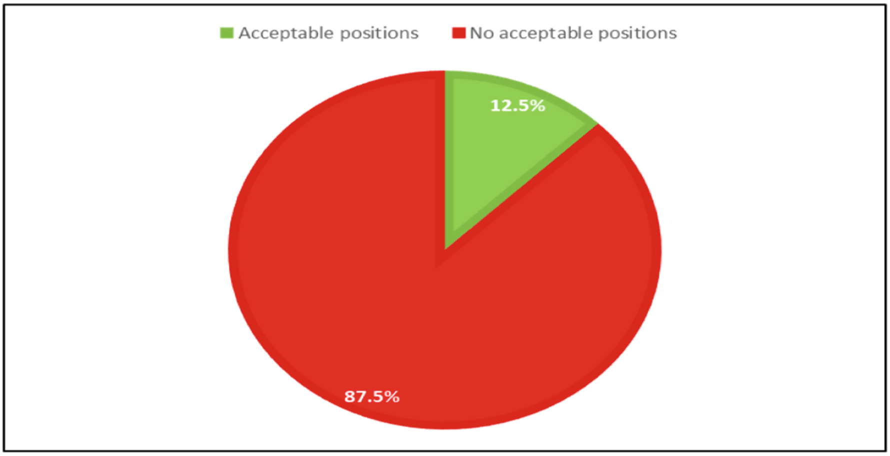

Fig. 1. Percentage of acceptable and unacceptable positions according to the ROSA checklist

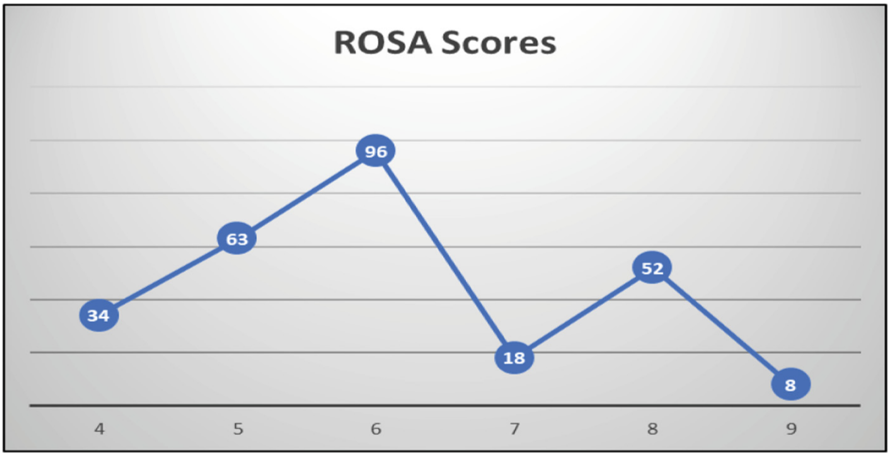

Fig. 2. Distribution of final scores according to the ROSA checklist

In relation to the seat pan height it was possible to determine that the most frequent problem is the insufficient space for legs beneath the desk surface (Fig. 3).

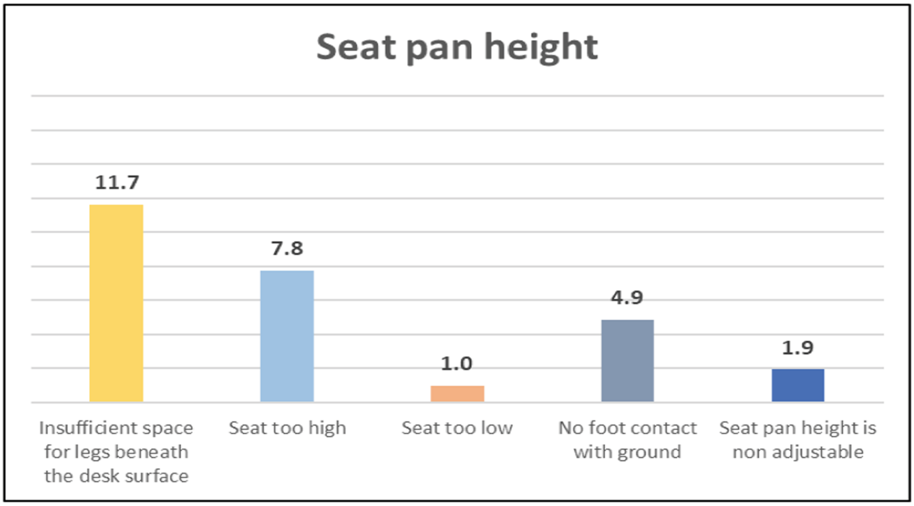

Fig. 3. Absolute percentage of the seat pan height characteristics

About the seat pan depth, it was possible to determine that the most frequent problem is its lack of adjustment (Fig. 4).

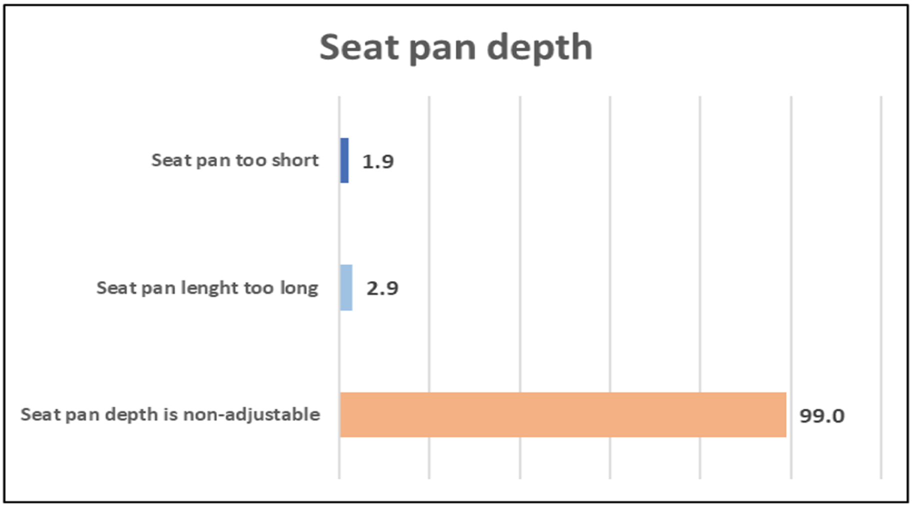

Fig. 4. Absolute percentage of the characteristics of the seat pan depth

Regarding the backrest of the seat its lack of adjustment and the absence of lumbar support are among the most detected peculiarities (Fig. 5).

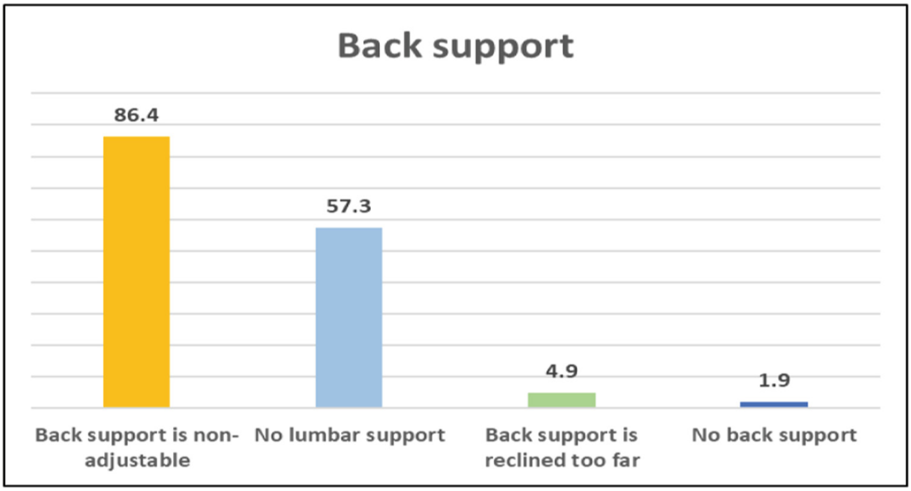

Fig. 5. Absolute percentage of the characteristics of the back support

The armrests as an important part of the chairs with ergonomic design is presented as non-adjustable and located very low without providing the respective support to the upper extremity (Fig. 6).

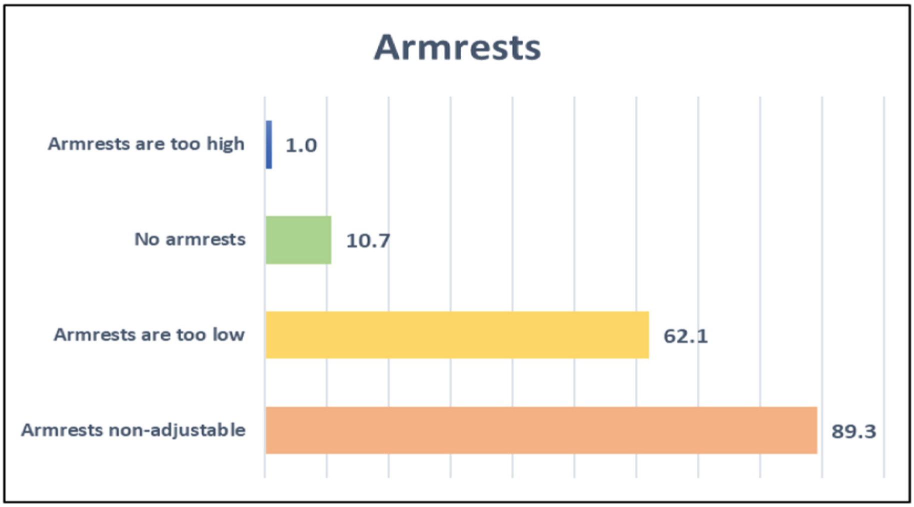

Fig. 6. Absolute percentage of armrest characteristics

The monitor in the evaluated positions is mainly below the horizontal visual field of the workers (Fig. 7).

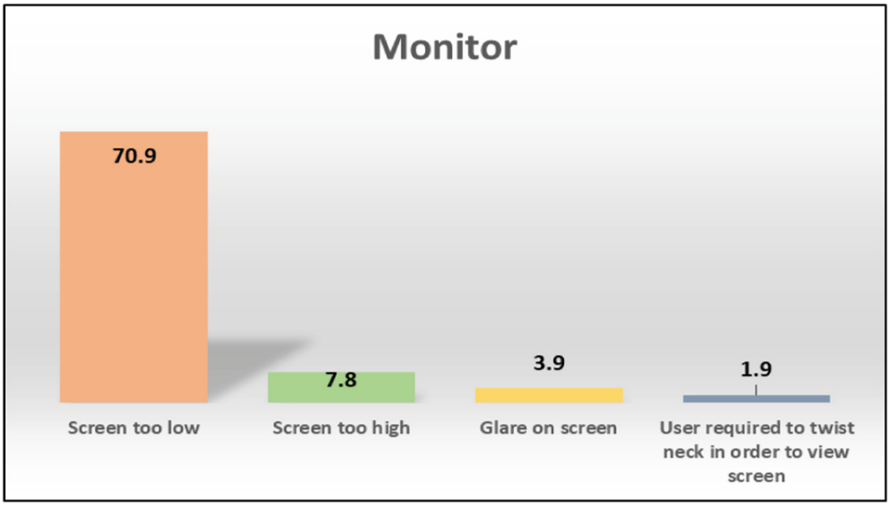

Fig. 7. Absolute percentage of monitor characteristics

The workers in a high percentage laterally deflect their wrists when interacting with the keyboard (Fig. 8).

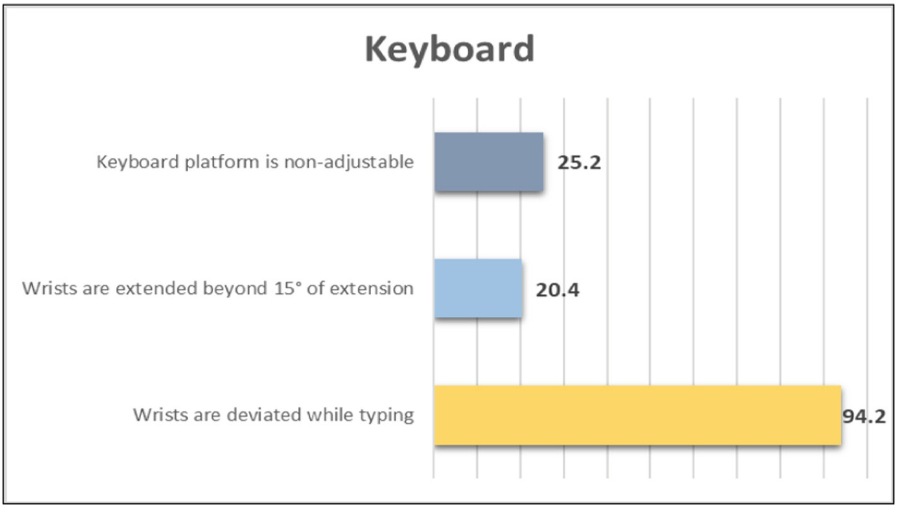

Fig. 8. Absolute percentage of keyboard characteristics

A high percentage of workers place the mouse outside the usual range, there is also the use of palm rest (Fig. 9).

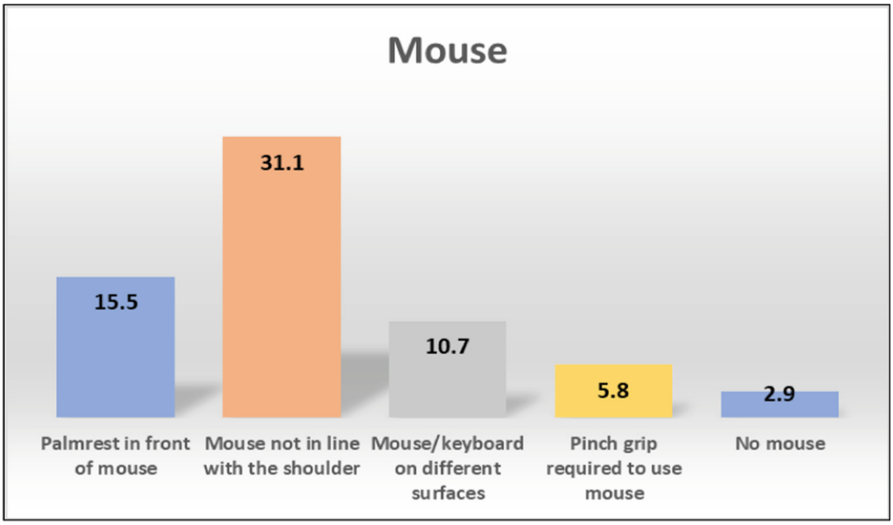

Fig. 9. Absolute percentage of mouse characteristics

A relative percentage of people use the telephone adopting bad postures and its location is given beyond 300 mm of the worker (Fig. 10).

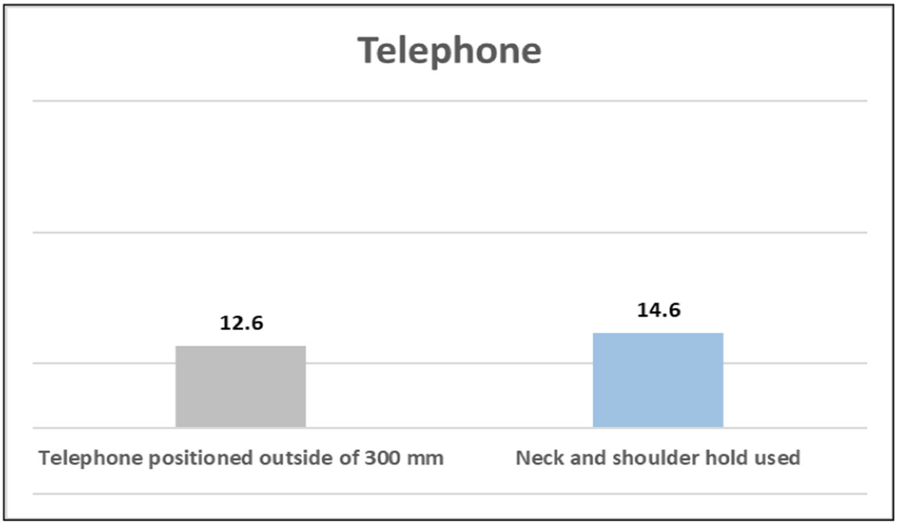

Fig. 10. Absolute percentage of telephone features

The overall results of the application of the RULA Method are (Table 1):

Table 1. RULA: scores and action level

Position type	RULA score	Action level
Desktop use	5	3
Laptop use	6	3

The scores per body segment in the administrative workstation that uses a desktop computer determine more postural load on legs, wrists, right arm and neck Fig. 11.

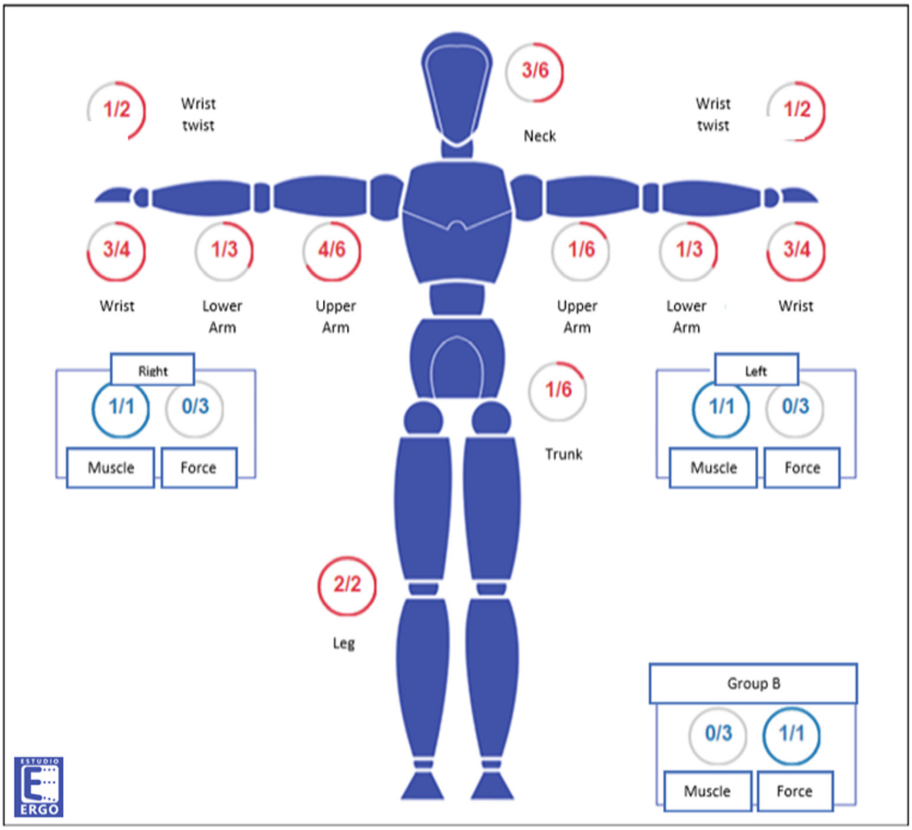

Fig. 11. RULA: score by body segment. Use of desktop computer

The scores by body segment in the administrative workstation that uses laptop determine as body segments more postural load on legs, wrists, right arm, neck and trunk (Fig. 12).

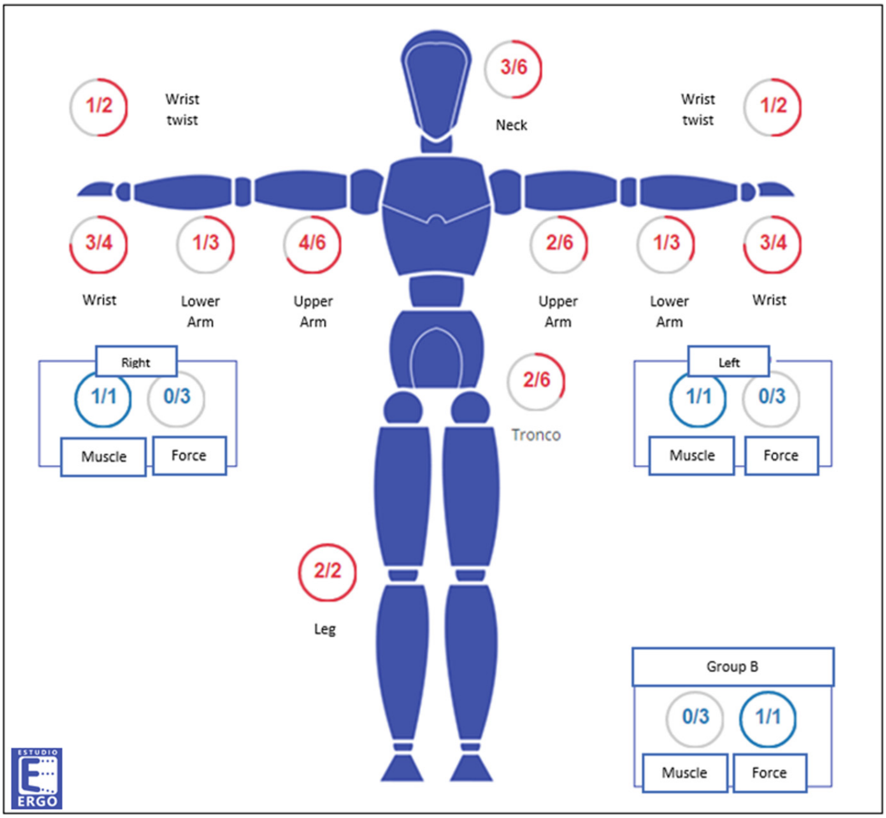

Fig. 12. RULA: score by body segment. Use of laptop

4 Conclusions

A high percentage of administrative jobs have ergonomic risks that are not acceptable due to the poor design of the work stations. The work tools are usually not adequate and the lack of training and information to the worker about their exposure to ergonomic factors is notorious.

It has been determined that most of the chairs used in administrative areas in the city of Quito do not have ergonomic characteristics, without the capacity of adjustment ranges in their backrest (86.4%) and depth (99%), their armrests also cannot be adjusted in height and width (89.3%) and being non-adjustable they are generally below the elbows flexed at 90° without providing the necessary support for the upper extremities (62.1%). There is a significant percentage of chairs that do not have armrests (10.7%), being an important element that provides comfort to workers and reduces the static load of the shoulders and arm muscles during the use of the mouse.

The chairs also do not have lumbar support (57.3%), a very important element to reduce mechanical overload in the lower back.

There are workers who due to their short stature and having to adjust the height of their chair to the work height they cannot support their feet on the ground (4.9%), so the provision of footrests is necessary.

It can be evidenced a percentage of work stations with insufficient space under the table (11.7%) due to the placement of boxes, folders or administrative tools in that space.

The keyboards used do not have gradual angulation capacity (25.2%), because portable computers are used or because the keyboard does not allow the regulation of their inclination. In this study we have been able to determine one of the most frequent bad postural habits is the radio-cubital deviation of wrists (94.2%) when interacting with the keyboard, this high percentage is largely due to the lack of information and training.

Another bad postural habit is the location and use of the mouse outside the normal range (31.1%), the use of the palm rest (15.5%) in tasks involving a high frequency of anteroposterior, lateral and transverse movement of the mouse. In addition, it could be established that the presence of keypads is low (10.7%), a suitable scenario since its presence leads to the positioning of the keyboard and the mouse at different levels and decreases the possibility of relaxing the position of lower limbs.

In the use of the telephone it has been possible to verify the existence of another postural malpractice such as its location between the neck and shoulder to use it while the workers interact with the keyboard and monitor (14.6%), as well as their distant and contralateral position to the motor dominance (12.6%).

Regarding the monitor, most of the workers place it below the horizontal vision plane (70.9%), causing a neck flexion greater than 20°, this location is partly due to lack of information or the use of laptops without a proper elevator.

The specific evaluation of forced postures allows us to verify that design problems or bad habits lead to the overload of body segments such as wrists, right arm, neck and trunk in administrative workers.

Due to the existing level of ergonomic risk, an ergonomic technical management should be established in the administrative areas in the city of Quito-Ecuador that allow the implementation of organizational measures such as information and individualized training for workers to minimize bad postural habits, and technical measures such as the provision of ergonomic chairs and necessary accessories.

An anthropometric profile of the Ecuadorian population should be developed so that in the future furniture and accessories can be designed according to the dimensions of our users to eliminate the current imbalance and reduce the incidence and prevalence of musculoskeletal disorders.

References

1. Instituto Nacional de Seguridad e Higiene en el Trabajo: Encuesta Nacional de Condiciones de Trabajo 6ª EWCS España. EWCS, Madrid (2017)
2. Allie, P.: Computer display viewing angles: is it time to shed a few degrees? In: Proceedings of the Human Factors and Ergonomics Society Annual Meeting, pp. 798–802 (2005)

3. Censos: Resultados del Censo 2010 de población y vivienda en el Ecuador. Fascículo Provincial Pichincha. INEC. Quito (2010)
4. Dowell, W.: An estimation of lumbar height and depth for the design os seating. In: Proceedings of the Human Factors and Ergonomics Society 39th Annual Meeting, pp. 409–411 (1995)
5. Lu, H.: VDT positions: effect on performance and comfort. In: Proceedings of the Human Factors and Ergonomics Society 37th Annual, pp. 397–400 (1993)
6. McAtamney, L.: RULA: a survey method for the investigation of work-related upper limb disorders. Appl. Ergon. **24**(2), 91–99 (1993)
7. Robertson, M.: Designing VDT operator training programs for preventing work related musculoskeletal disorder. In: Proceedings of the Human Factors and Ergonomics Society 38th Annual Meeting, pp. 429–433 (1994)
8. Shute, S.: Effects of adjustable furniture on VDT users. Hum. Factors **26**, 157–170 (1984)
9. Sonne, M.: Development and evaluation of an office ergonomic risk checklist: ROSA - rapid office strain assessment. Appl. Ergon. **43**(1), 98–108 (2012)
10. Stammerjohn, L.: Evaluation of work station design factors in VDT operations. Hum. Factors **23**, 401–412 (1981)

Occupational Health and Safety Challenges Among Small and Medium Sized Enterprise Contractors in South Africa

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Abstract. The study examined the occupational health and safety challenges among SME's Contractors in Gauteng Province, South Africa. The data in this paper was obtained from secondary sources, which comprised of reliable and related scholarly literature namely: articles, journals, books, etc. from all that a detailed literature review was compiled. Furthermore, the data was obtained from primary sources as well; the questionnaires were dispersed to different companies in the construction industry. From the 70 questionnaires distributed, 42 were brought back and they were all valid and usable. Descriptive statistical analysis was adopted for the study. The research revealed that the challenges faced by SMe's contractors in South Africa, were lack of skills, experience and education, lack of knowledge of pricing document, effective communication skills, lack of H&S education, poor regular inspections on sites, poor technical skills, the ignorance of regulatory obligation, lack of finance and lack of business skills. The research point out that safety and health of the workers is not negotiable, is all pervasive, increases productivity, and leads to better performance, improve the company image, reduced claims and accidents also reduce lost times spent on injuries and property loss. Emphases on the OHS level of implementation is greatly urged to be implemented non-stop to overcome the challenges facing the SME's contractors.

Keywords: Construction industry · Occupational health and safety
Small and medium enterprise

1 Introduction

The establishment of a workplace that minimizes active risks and hazards, and emphasis towards the implementation of mitigating factors to either reduce or eliminate these risks and hazards was promoted to be used [1, 2]. Identified that productivity and quality, which are vital elements of the value chain on a construction site, are negatively affected by poor health and safety performance.

Construction workplaces are potentially seen to be the most risky and a place where accidents are common in any working environment. Therefore, workers are at the risk of injury and in extreme cases death, if their exposure to construction sites is not

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controlled [2, 3]. It is necessary for construction firm to identify all dangers and possible hazards that are likely to occur, during construction operations in order to prevent their occurrences [3].

According to [4], construction is described as a "dangerous, risky and hazardous task, to emphasize the above statement the United Kingdom, [5, 6], agreed that in the last twenty-five years alone over 2800 construction workers have died of construction accidents, with even more workers having suffered from serious injuries. "This is an unacceptably high figure and the industry needs to devise proper solutions to these problems" [7].

The construction industry has the highest injury and fatal rates [4]. In theory, most construction injuries sustained on site can be prevented or controlled. Unfortunately, this goal became unachievable and compliance among the stakeholders has been very inactive [8]. Prevention and control of risk in construction industry is a consistence global challenge, construction have been considered having the worst safety records among its diverse economic sectors of its kind.

In addition to the loss of life and reduction in the quality of life of construction workers, construction incidents lead to project delays, increased project costs, medical burdens, and other negative consequences [9]. The World Health Organization [WHO] [10] estimates that sub-Saharan Africa experiences approximately one tenth of the world's occupational injuries and fatalities, and approximately 7.5% of the world's population.

The rates are twice that of the established market economies, and fewer than half of the resources of those available in established market economies to manage the risks and their impact. This implies that countries in the Southern African Development Community [SADC] need to adopt plans to improve occupational health and safety that reach high-risk groups and areas in an efficient and cost-effective manner [10].

According to [11], the construction industry creates employment and serves as a means of generating income for many people and as a means of application of technologies in various degrees. Therefore, the sector engages about 240000 workers in South Africa thus contributing significantly to the gross domestic product (GDP) [12]. However, the sector is associated with high risks particularly for workers notwithstanding its importance in the social and economic development in South Africa [9, 13]. Nonetheless, the construction industry can be interlinked with the economy of a country and is often an indicator of how healthy the state of the said economy is. Therefore, if the construction sector and the economy of a country are linked, it is necessary for the sector to effectively attend to the welfare of the workers in that industry [9].

While Health and Safety [H&S] is the responsibility of everyone at work, construction companies have to be aware that they are responsible for managing and improving issues related to H&S on construction sites [14]. This is so because construction, largely, is a labour intensive industry and depends on the availability and safety of workers to complete current and future projects [4]. Despite refined H&S regulations in most countries, high rates of accidents and fatality persist. The regulations and procedures intended to prevent such accidents are usually mandated by the appropriate occupational safety authority in each country [15].

The academics and professionals within the construction industry believe that regulations and legislation on their own cannot achieve the desired goal of zero accidents and incidents on construction sites, but the latter can be achieved with the involvement of the stakeholders in the industry [4]. Adherence to regulations and legislation is not the only way to ensure safety on the working environment. However, it provides a basis for the employment and enforcement of good construction practices at minimal cost [16].

Small and medium-sized enterprises are faced with a number of challenges when it comes to complying with occupational health and safety (OSH) regulations owing to fewer resources and less awareness of the costs of non-compliance in terms of higher risks. Employee OSH representatives are frequently lacking, especially in smaller companies, making it more difficult to implement the participatory approach foreseen by the 1989 EU Framework Directive on health and safety [17, 18]. This research will investigate the challenges faced by small medium enterprises in implementing the occupational health and safety rules in the work environment and creating it as culture to by in their companies.

2 Literature Review

Challenges Faced by SMME'S
Presently, SME owners in South Africa have numerous challenges to overcome. [19] Compiled the following list of most burning issues that business owners face today:

- A lack of business skills, this is because of a poor education system and little or no culture of entrepreneurship;
- A lack of finance, financial institutions will only lend money to low-risk clients and the cost of banking is high;
- High costs, the cost of raw materials and telecommunications is high;
- Poor skills of employees, the government skills development system is not assisting SMEs;
- Bargaining councils, they have become huge conspiracies in which smaller businesses are crushed; the CCMA, time is wasted because employees can take their employers there for the smallest whim;
- The black economic empowerment; businesses are still confused by the multitude of criteria set out in the codes. Many owners also pay consultants huge sums of money to obtain ratings they do not yet require; the crime; the stock theft as an example obviously has a negative effect on some of the SMEs; the exposure; the business owners do not portray themselves well.

Construction Industry and Occupational Health and Safety in South Africa
Worldwide, the construction industry contributes a large number of injuries. However, construction in developing countries, including South Africa, performs worse than construction in developed countries [20]. Furthermore, there is a high level of non-compliance with H&S regulations in South Africa. Previous research findings indicated that, at the organizational and site level, this poor performance in construction H&S is

attributable to a lack of management commitment, inadequate supervision, and inadequate or lack of H&S training [20].

Moreover, a lack of workers involvement, personal risk appreciation and work pressures also contribute to poor performance. Management and leadership at all levels are therefore important to improve construction H&S in South Africa [21]. The cost of an accident (CoA) contributes substantially to the cost of construction, which in turn creates a financial motivator for all stakeholders (including clients) to address H&S [22]. Internationally and in South Africa, poor H&S performance is often attributed to a lack of respect for workers in the building construction industry in which the workforce is treated as a low-value transient resource with little investment in their development and insufficient attention to their welfare [23].

An understanding of construction H&S is handicapped by lack of available statistics, and in particular that from the Compensation Commissioner. The 1999 statistics [20] indicated that the construction industry accounts for around the third highest number of fatalities per 100 000 workers, and the ninth highest number of permanent disabilities per 100 000 workers. The fatality rate in the construction industry is approximately 20 per 100 000 workers, or approximately 150 fatalities per year excluding construction-related motor vehicle accidents, Motor vehicle accidents account for approximately another 100 fatalities per year [20]. The high rate of non-compliance with the requirements of the Construction Regulations, which amounted to 50% of construction sites, indicates that H&S in the construction industry in South Africa lags significantly behind compared to other developed countries [24].

Small and Medium Enterprises (SME's) Contractors in South Africa

The following concerns about the growth and development of SMEs were also identified by [25–28]:

- The smaller the enterprise size-class, the less significant as an employer it tends to be in most sectors, but more significant in the construction and retail trade.
- There are still substantial interprovincial inequalities in terms of economic performance, job opportunities and poverty.
- As the enterprise size-class increases, the percentage owned by Asians, coloureds and Africans decreases, meaning that larger enterprises are owned by whites.
- There is a predominance of African female ownership in certain sectors that is welcomed, but most of this involvement is in the survivalist or microenterprises. By definition, the wealth and employment generated here are constrained.
- Ownership constraints are particularly severe for entrepreneurs (especially women) in rural areas.
- Low-wage competition is discouraged by legislation, thereby discouraging labour intensive activity.
- There is a small customer base.
- Interest rates are high and there is limited or no access to capital.
- There are insufficient government contracts and weak support programmes.
- International trade is limited.
- Plans and technology are outdated.
- Management skills are inadequate resulting in poor management.

3 Research Methodology

Quantitative approach method was adopted to identify the occupational health and safety (OHS) challenges facing small medium – sized (SMEs) contractors. Structured questionnaires were used to collect facts, opinion and views. The study was carried out in Gauteng Province of Republic of South Africa, on small and medium enterprises (SME's) contractors registered with construction industry development board (CIDB) of South Africa. The response rate of the respondent to the questionnaire was very high, out of the 70 questionnaires sent out, 42 were received back which represent 60% response rate, all of the questionnaire were usable.

In this study, the analysis employed simple statistical methodology, which is descriptive statistics (mean, mode, median, number, percentage, range, standard deviations). Respondent were required to respond to question based on the five point likert scale. The Likert scale was used because it allows a range of responses to be generated including neutral answers and does not force a decision as in the case of "yes" or "no" type of questions. The mean item score was adopted to rank the factors from highest to lowest. The Mean Item Score (MIS) is expressed and calculated for each item as follows:

$$\mathbf{MIS} = \frac{1n1 + 2n2 + 3n3 + 4n4 + 5n5}{\Sigma \mathrm{N}}$$

Where;
n1 = number of respondents for strongly disagree
n2 = number of respondents for disagree
n3 = number of respondents for neutral
n4 = number of respondents for agree
n5 = number of respondents for strongly agree
N = Total number of respondents

4 Findings and Discussion

Level of Implementation of OHS in SME's Contractors
The study revealed that 33% of the responded felt that the level of implementation of OHS, it was practiced between 60–70%, 31% of the respondent believed that it was practiced between 80–90%, 24% between the range of 30–50% and 12% between the range of 90–100% (Fig. 1).

Table 1 reveals the extent of factors that hinder the implementation of OHS in the SME'S contractors, The responded rank Lack of regular inspections and audits the highest with a MIS = 4.40 and STD = .964; Lack of management/supervision/information flow; Poor material and components was ranked 2 with a MIS = 4.31 and STD = 0.924 and 1.047 respectively; Lack of management commitment was ranked 3 with MIS = 4.29 and STD = 0.970; Lack of equipment and tools was ranked 4 with and MIS = 4.21 and STD = 0.976; Poor communication between workers was ranked 5th with MIS = 4.17 and STD 0.853; Lack of employees involvement was ranked 6th with MIS = 4.14 and

STD = 1.049; Lack of training and risk education was ranked 7th, with MIS = 4.12 and STD = 1.109; Lack of skilled workforce was ranked 8th with MIS = 4.10 and STD = 0.983; Work area access was ranked 9th with MIS = 4.02 and STD = 1.024; Poor work/jobsite conditions ranked 10th with MIS = 3.98 and STD = 0.924; Lack of sub-contractors involvement was ranked 11 with MIS = 3.95 and STD = 1.147; Lack of incentive for good performance was ranked 12 with MIS = 3.93 and STD = 1.135; Lack of investigations and risk assessments was ranked 13th with MIS = 3.83 and STD = 1.208.

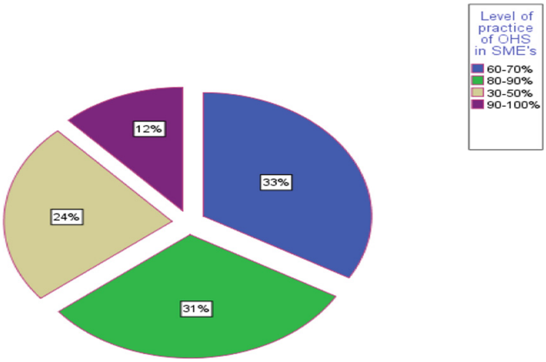

Fig. 1. Level of implementation of OHS in SME'S

Table 1. Hindrance of Implementation

Descriptive statistics	MIS	Std. Dev	Rank
Lack of regular inspections and audits	4.40	.964	1
Lack of management/supervision/information flow	4.31	.924	2
Poor material and components	4.31	1.047	2
Lack of management commitment	4.29	.970	3
Lack of Equipment and tools	4.21	.976	4
Poor communication between workers	4.17	.853	5
Lack of employee involvement	4.14	1.049	6
Lack of training and risk education	4.12	1.109	7
Lack of skilled workforce	4.10	.983	8
Work area access	4.02	1.024	9
Poor work/jobsite conditions	3.98	.924	10
Lack of subcontractor involvement	3.95	1.147	11
Lack of incentive for good performance	3.93	1.135	12
Lack of investigations and risk assessments	3.83	1.208	13

Challenges Facing SME's Contractors

The study revealed that most of the respondents believe that Lack of knowledge of pricing document was critical challenge they were facing hence ranked highest (1) with MIS = 4.98, STD = 6.261; followed by Communication shortfalls and Lack of H&S education were ranked second with MIS = 4.05,STD = 0.697 & 0.854 respectively; Infrequent inspections was ranked third with MIS = 4.02, std = 0.749; Poor technical skills; The ignorance of regulatory obligation and Ignorance of contractual rights were ranked fourth with MIS = 43.90, STD = 0.692, 0.790 & 0.938 respectively; Lack of internal H&S competence and Inadequate H&S training were ranked fifth with MIS = 3.83 and STD = 1.034 & 0.908.

Slowness in promoting OHS and In competent employees were ranked sixth with MIS = 3.76 & 0.932 for both of them; Reporting shortfalls was ranked seventh with MIS = 3.74 & STD = 0.828; Lack of managerial skills was ranked eighth with MIS = 3.71 & STD = 0.918; Lack of resources, time and money was ranked ninth with MIS = 3.64 & STD = 1.100; Lack of financial skills and Lack of qualified safety officers on site were ranked tenth with MIS = 3.62 & STD = 1.081 and 1.147 respectively. Inadequate attention given to OHS was ranked eleven with MIS = 3.57 & STD = 1.016; Higher compliance, Difficult to get funding from financial institution, Lack of health and safety training and Poor health and safety culture were ranked 12th with MIS = 3.55 & STD = 0.993, 1.347, 1.194 & 1.041 (Table 2).

Table 2. Challenges faced by SME'S

Challenges	MIS	Std. Dev	Rank
Lack of knowledge of pricing document	4.98	6.261	1
Communication shortfalls	4.05	.697	2
Lack of H&S education	4.05	.854	2
Infrequent inspections	4.02	.749	3
Poor technical skills	3.90	.692	4
The ignorance of regulatory obligation	3.90	.790	4
Ignorance of contractual rights	3.90	.983	4
Lack of internal H&S competence	3.83	1.034	5
Inadequate H&S training	3.83	.908	5
Slowness in promoting OHS	3.76	.932	6
In competent employees	3.76	.932	6
Reporting shortfalls	3.74	.828	7
Lack of managerial skills	3.71	.918	8
Lack of resources, time and money	3.64	1.100	9
Lack of financial skills	3.62	1.081	10
Lack of qualified safety officers on site	3.62	1.147	10
Inadequate attention given to OHS	3.57	1.016	11
Higher compliance	3.55	.993	12
Difficult to get funding from financial institution	3.55	1.347	12
Lack of health and safety training	3.55	1.194	12
Poor health and safety culture	3.55	1.041	12

5 Conclusion

The study revealed that occupational health and safety was well known by the SME's, however less implemented due to challenges they faced in the industry, such as lack of knowledge of pricing document. Reason being small medium enterprise don't have the background of construction they merely take it as business. Poor communication, lack of health and safety education and poor technical skills were the top five challenges that SME's faced. Moreover, the study also revealed the factors that hinder the implementation of occupational among the SME's which were the lack of regular inspection and audits, lack of management supervision, lack of information flow, poor material and components, lack of management commitment, lack of equipment and tools, poor communication between employees and lack of training ad risk education. Therefore, training/education on occupational health and safety is mandatory for the SME's and there must be an onsite health and safety office every day and the money to pay must be included in the BOQ. In order to avoid poor implementation of OHS and excuses that the health officers are expensive.

References

1. Occupational Safety and Health Administration: Construction Safety and Health: Fall Hazard Participant Guide. U.S. Department of Labour SH–07-06-F-36 (2012)
2. Smallwood, J.J.: The influence of engineering design on health and safety during construction. J. South Afr. Inst. Civil Eng. **46**(1), 2–8 (2012)
3. Hunter, C.M.: Six Construction Site Hazards, Construction Induction, Construction Safety, Construction Safety Images. Riskex (2011)
4. Haupt, T.C.: The Performance approach to construction worker safety and health. Ph.D. Dissertation, University of Florida, Florida (2001)
5. Cameron, L., Duff, R., Gillan, G.: Health and safety executive: a technical guide to the selection and use of fall prevention and arrest equipment. Published by Glasgow Caledonian University (2009)
6. Chartered Institute of Building: Health and Safety in the Construction Industry. CIOB supports a zero tolerance approach to unsafe and unhealthy practices (2008). http://www.hse.gov.uk/humanfactors/comah/common. Accessed 09 June 2016
7. Chartered Institute of Building.: Health and Safety in the Construction Industry. Health and Safety Executive (2009). http://www.hse.gov.uk/humanfactors/comah/common. Accessed 08 June 2016
8. Gambatese, J.A., McManus, J.F.: Discussion of the constructability review process: a constructor's perspective. J. Manage. Eng. **15**(1), 93–94 (1999)
9. James, P.M., Braam Rust, A.A., Kingma, L.: The well-being of workers in the South African construction industry: a model for employment assistance cape peninsula university of technology (2012)
10. Loewenson, R.: Assessment of the health impact of occupational risk in Africa: current situation and methodological issues. Epidemiology **10**, 632–639 (2012)
11. Mitullah, W.V., Wachira, I.N.: Informal Labour in the Construction Industry in Kenya: A Case Study of Nairobi. Sectorial Activities Programme A 10020499 999. ILO, Geneva (2003)

12. Ramutloa, L.:. Department of Labour Republic of South Africa, Amended Occupational Health and Safety Act [2007] 2-27 (2007)
13. Brace, C.L., Gibb, A.G.F.: A health management process for the construction industry: In: Haupt, T., Smallwood, J. (eds.) Rethinking and revitalizing Construction Safety, Health and Quality. Port Elizabeth, South Africa (2005)
14. Davies, V.J., Tomasin, K.: Construction Safety Handbook: Hardcover, 2nd edn. Thomas Telford Ltd., 303 Kurasa, Kuchapishwa (2000)
15. Gee, A.F., Saito, K.: Construction loads and other safety measures specified by U.S., U.K. and Japanese Bridge Standards: In: Ratay, R.T. (ed.) Construction Safety Affected by Codes and Standards, Proceedings of a session sponsored by the Design Loads on Structures During Construction Standards Committee and the Performance of Structures During Construction Technical Committee of the Structural Engineering Institute, Minneapolis (2000)
16. Ratay, R.T.: Structural condition assessment: for serviceability, rehabilitation, retrofitting, adaptive reuse, code compliance, and vulnerability, vol. 2000, pp. 5–8 (2001)
17. Deacon, C.H.: The Health Status of Construction Workers: Dissertation work Submitted in Fulfilment of The Requirements for Master Degree in Creationism in the Faculty of Health Sciences at The University of Port Elizabeth (2003)
18. Latief, Y., Suraji, A., Nugroho, Y.S., Arifuddin, R.: The nature of fall accidents in construction projects: a case of Indonesia. Int. J. Civil Environ. Eng. **11**(05) (2011)
19. Taylor, F.: General model of accident rate growth in the construction industry. J. Civ. Eng. Manage. **13**(4), 255–264 (2007)
20. South Africa. Department of Labour. Occupational Health and Safety (OH&S): Inspectorate in relation to the construction industry. Government Gazette 539 (2010) 33176 (2011)
21. Health and Safety Executive: Top Tips for Ladder and Stepladder Safety: An Employer's 'Guide INDG405 HSE Books (2012). ISBN 0 7176 6105 9
22. National Institute for Occupational Safety and Health: Preface to the special section on occupational fall prevention and protection (2010). http://www.cdc.gov/niosh/topics. Accessed 06 July 2016
23. Geminian, I.F., Smallwood, J.: A critical review of the effectiveness of the safety: Department of Labour (DoL) Occupational Health and Safety (OH&S) Inspectorate in relation to the construction industry in South Africa (2010)
24. Taylor, G., Easter, K., Hegney, R.: Enhancing Occupational Safety and Health. Elsevier Butterworth-Heinemann, Burlington (2004)
25. Occupational Health and Safety Act 85 of 1993: Juta's Status Editors and Workplace Solutions, 9th edn. (2009)
26. Lewis, J.: Construction Site Accidents-Falling Object (2012). http://www.jlewislaw.com/2012/construction-site-accidents-fallingobjects. Accessed 10 May 2016
27. Cooke, B., Williams, P.: Construction Planning, Programming and Control. Wiley-Blackwell, Chichester (2009)
28. Chi, C.F., Chang, T.C., Hung, K.H.: Significant industry-source of injury accident type for occupational fatalities in Taiwan, accidents facts: United State of America National Safety Council. Int. J. Ind. Ergonomics **34**(113), 77–91 (2004)

Dynamics of Resistance in the Change Process

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Abstract. The article presents the results of identification of dynamics of behaviour in response to introducing changes. The aim of the considerations was to determine the strength of resistance to changes. Identification of dynamics was performed through analysis of reaction of a given subsystem to implementation (extortion) of changes. A set of extortions applied upon realising processes of implementing changes in the studied organisations is presented in the article. Observation of effects achieved by a given object was the basis for determining dynamic parameters of the analysed object. The resistance was identified as a decrease in effectiveness of work of a given part of the organisation in the form of a significant decline of the curve illustrating a reaction of the system to change.

Keywords: Human factors · Dynamic of interaction · Resistance
Changes implementation · Industry 4.0 · System dynamics

1 Introduction

One of the most difficult issues while implementing changes is to convince people to take proper action. When the significance of objectives is determined, a reference to the systems of values is made in order to attribute proper value to particular elements. This stage is devoted to shaping and connecting needs, beliefs, values, mental models and aims in order to influence the analysed object and deed, at the same time formulating a structure of reference.

It is important to convince workers to change their perception, which means changing certain aspects of deep perception systems or the way they are used (for shallow persuasion) or what they are (for deeper persuasion).

Of course, there exist a huge number of persuasion systems, but when a person is resistant to changes, everything that has to be done is to help this person see the change in a different light, in this way altering the structure of his/her perception.

There exist numerous concepts of managing a change process. They originate from various trends and have been developed by theoreticians and practitioners of management. They differ in terms of approach to methodology of introducing changes.

Particular stages in the model of changes have different names. Yet the process of change can be reduced to 3 phases [1]: detachment from the past, transforming the

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current state, strengthening organisation for future activities. On the basis of proposals for methodology of processes for realising changes Mikołajczyk provides his own model [2]. In this study the basic stages of cycle of changes are the following: preparation phase, implementation phase, evaluation phase. The authors believe that since Taylor – Le Chatelier organisational cycle was formulated, proposals by various authors actually have only been expanding it and enriching it with more details. Still it has to be admitted that development of management systems, technology and science of management itself undoubtedly cause significant and meaningful detailing of particular stages of change cycle. Classical and contemporary approaches to realisation of change processes are based on a group of theories in psychology and sociology. Knowledge of the bases lying at the source of different techniques of realising changes may facilitate better shaping of implementation processes and tools.

2 Realisation of Change Process and Emergence of Resistance – the Research

The aim of the research process is to describe dynamic properties of organisation elements undergoing changes with a purpose to determine a methodology of efficient control of change implementation cycle, but first of all the objective is to identify the phenomenon of resistance.

Analyses were carried out during 17 months in a group of 29 enterprises. The enterprises had been selected taking into account variety of organisational structures and basic technologies and manufacturing processes. Sociological and identification analyses were carried out for all the enterprises. Also, dynamics of changes implementation were analysed, which facilitated development and establishing of models.

A substantial part of the research consisted in registering effects and reactions to forcing changes, which was performed for selected (one-person) posts and groups of workers. The registration was performed through observing the course of normal organisational processes in a real socio-technological-information environment. Employees were a subject to non-participating observations, so that they did not regard the act of observation as a kind of supervision or inspection that could be associated with any forms of sanctions. Such a state was achieved because the workers already knew the observers, who had conducted numerous interviews with the crew in the earlier preparatory stages. Thus, the workers knew that the researchers played neutral role in relation to the tasks the crew realise. Achieving this state was very important for maintaining a standard of normal course of processes. It is so because usually workers are suspicious towards persons who observe their work, register effects and additionally come from outside of the organisation with unknown intensions.

Depending on recipients of particular analyses (investors, customers, collaborators, board, employees, public opinion) changes successes can be assessed with the use of different methods taking various forms.

During the process of analysing the course of changes in the studied enterprises parameters were registered by using of the method of collecting quantitative data about the state of processes. In some cases, these methods were based on a system of automatic collecting of information about processes (in particular in cases of production operations or other transactional operations using computer systems). Remaining cases required registering specific parameters by an employee who performs the job of the process observer [3, 4].

The enumerated objects were a subject to observations during the realisation of normal procedures of implementing changes. These observations that referred to implementations realised following the rule: communication –forcing –settlement had a significant research value.

Graphs illustrating responses in the function of time are presented in the article. On y-axis an amplitude scale is used with no units determined, according to which value 1 represents the target level of the effect that is aimed to be achieved through realisation of the change process.

2.1 Situation 1 – Change of Production Order

Change of production order, although often concerning the whole unit, was observed on the level of a single worker and executive teams, whereas enterprises realise production tasks in series. The production has a medium volume and high volume, particular series are manufactured depending on the appearing demand for a product. Sales department, upon having diagnosed the demand for a specific assortment, causes organising production tasks into itineraries. Production division realises tasks following the priorities attributed to these tasks under production planning. The aforementioned change consists in sudden modification of tasks priorities, which causes disorientation of direct producers. Most commonly workers have not been informed well enough about the reasons and consequences of the modification. Doubts emerge in relation to accuracy of accounting for tasks performed so far. In enterprises where changes are permanent, disorientation is less prominent. In most cases (73%) the employees quickly took up new configurations of tasks, treating the emergent circumstances with understanding (Fig. 1).

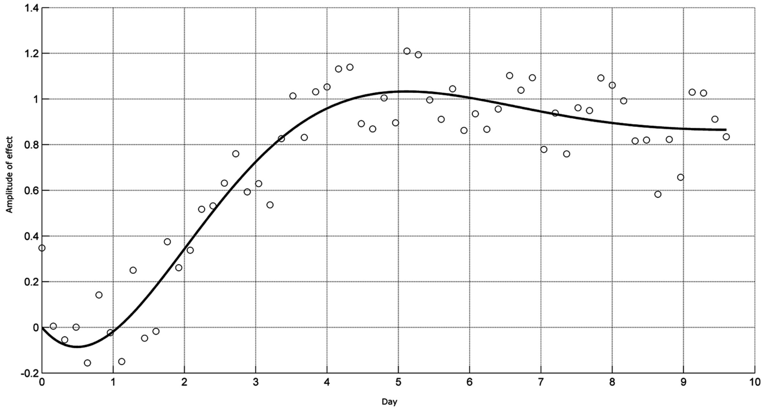

Fig. 1. Reaction to change of a production order, automatic acquisition.

The adaptation meant adjustment to new efficiency and quality requirements towards an ordered production. In 87% of cases a new production order originated from a group of tasks realised earlier, therefore the employees were getting acquainted with the rules of performing the job, and they had to have necessary equipment and knowledge. Production system was also properly adjusted to the change of production order (material provisioning, intermediate storage places, means of internal transport, tools and workshop aids supply).

Due to the fact that the change of order was not always performed with regards to the whole planning circle (in 32% of cases) problems with synchronising tasks on technological line were encountered, which caused the effect of bottle-neck (too low efficiency on the post performing proceeding operations or too high efficiency on the subsequent post). As enterprises realised tasks under typical production orders, stabilisation of production stream flows between posts took place by itself thanks to offhand interventions.

2.2 Situation 2 – Increase of the Target Value of Process Capability Index Cp

Observations were not carried out for single persons because aggregation and analysis of capacity indexes were performed in long periods and concerned whole divisions. Process capacity indexes are used to determine the quality level for processes in enterprises. Organisations determine them and use them for analysis of the state of process quality in time scale. They follow the changes of the parameters in order to obtain the information about dynamics of quality development in company. Capacity indexes are an excellent tool for equalising the quality level of processes in the scale of the whole organisation, because with their use technologically unrelated processes can be compared. It is also a useful tool for analysing dynamics of changes implementation in quality (Fig. 2).

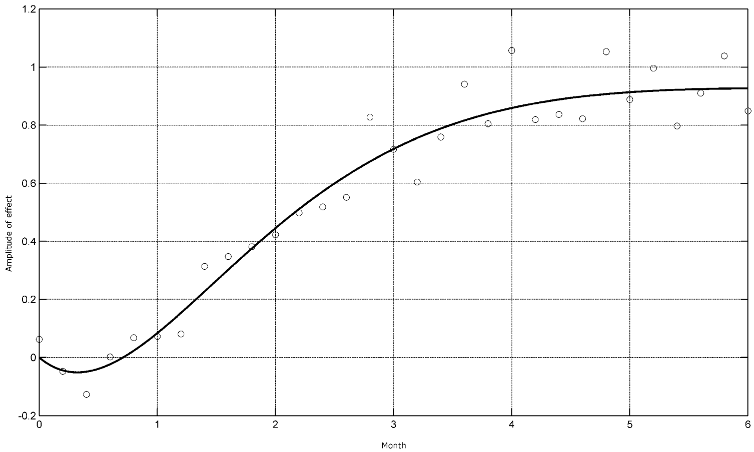

Fig. 2. Reaction to Cp change, automatic acquisition.

Very often organisations focusing on quality possess systems for continuous collecting and processing information about state of processes [5]. The information is collected with the use of automatic devices and archived in a continuous mode in electronic databases, thanks to which it is possible to perform multicriteria analysis of the collected material [6]. During the research an access was obtained to a number of such bases and collections of data on processes. It was possible to follow in detail reactions to exerted forcing in the form of improvement or decline in adequate capability index. Process capability is a slow-changing parameter, because it depends on long-term investments and actions taken for the benefit of quality, with a wide organisational range. Therefore, analyses were carried out as observations of long-term changes with a wide range [7].

The authors observed in the organisations that approaching the assumed capacity level of Cp or Cpk process was the goal of the chief management. Implementation of improvement actions was preceded by appropriate preparations of the whole system. Only the effect of direct Cpk change after initiating an improvement programme was registered. Companies in which pro-quality approach is applied and in which process improvement is supervised in a rational way are minority in the studied group. Initiating the improvement phase indicates ambitions and remarkable abilities of organisation to self-improve. This means that decisions about implementation of improvement programme Cpk were taken reasonably, therefore the effects that the companies achieved and predominantly the dynamics of achieving them reflected the real abilities and state of the organisation.

2.3 Situation 3 – Reducing the Fraction of Production Rejects by Several Percentage Points

Similarly, to the previous case, this implementation of changes is associated with quality improvement. Yet in contrast to the enterprises from the previous case, in this case in the studied companies there exist no integrated systems of quality improvement. Nevertheless, this absence does not mean that the organisations do not perform certain activities to improve quality [8]. They introduce improvements consisting in reducing errors in producing goods and services. An extortion meant assigning a goal of reducing the level of rejects (errors) by a certain number of percentage points. The crew approached this type of tasks (extortions) as a limitation that is forced and is not conducive to “quiet work”. In many cases (36%) workers claimed that articulating the requirement to reduce the number of rejects was a result of managers’ dissatisfaction based on non-substantive foundations. According to these workers, assumed that their job had been assessed correctly until that moment, the new demands were either a “nit-picking” (according to 22%) or they were yet another tool to oppress the crew (14% of votes). The demand was perceived as a form of rising the performance norms. The workers even claimed that had they not demonstrated their efficiency at work, they would not be demanded to achieve even better results.

Still the average behaviour was to get adjusted to new requirements of work quality. In spite of the initial annoyance the crew did not demonstrate intentional resistance and counteracting implementation of change. The symptoms of minor resistance resulted from the fact that the workers had to learn working according to new, more rigorous standards (Fig. 3). After the period of acquiring skills, the workers entered the stage of performing work according to the newly established requirements.

In predominant number of cases the workers who were already persuaded to change their approach to processes towards seeing it as the cycle of continuous improvement articulated questions that could be generalised into the following one (a symptom of intentional resistance): if a priority in processes improvement is to eliminate the activities that do not increase the added value, what is the objective behind taking actions to find the reasons for deterministic variations in the process when no rejects are noted? Searching for the reasons shifted the persons' engagement from performing production tasks towards checking potential reasons for dysregulation of process. Why not wait until the process gets dysregulated enough to cause rejects and only then take actions? It is also possible that the appearance of rejects due to the reason of process dysregulation caused additional costs (material and financial) and did not result in any visible improvement besides bringing the process to a statistical state of stabilisation.

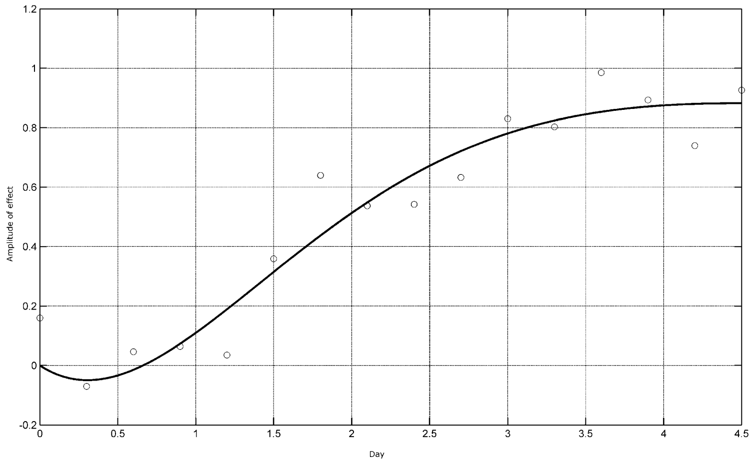

Fig. 3. Reaction to change in fraction of rejects, manual acquisition.

This stabilisation is also questioned as a benefit, because opponents claim that the threat was only imaginary, and there was no need to stop production and "nit-pick". Yet it should be noticed that some benefits are delayed in time hence not immediate. An undoubted benefit yet located out of perception of line workers (at least in the beginning of the process), is eliminating potential reasons for nonconformities or the reason for deterioration of Cp process capability. Eliminating the reasons of nonconformities (when rejects already appear) as well as potential reasons of possible nonconformities is among priority activities while improving processes. They can have the character of preventive, adjustive or corrective actions.

What is then the added value of the process of identification of potential reasons for statistical dysregulation? This value is represented by the knowledge about how a process behaves, what happens with it, about sensitivity of the process to actions and disruptions. This knowledge is a valuable common resource to be used for the whole class of similar posts. In the future, when a process gets dysregulated in a similar way or when a certain non-accepted fraction of rejects appears at any of the work posts in a given class, it will be possible to read the records from the process documentation on potential reasons of a similar condition from the past.

Yet in order to be able to analyse processes improvement in the above way, a determination, vision and realisation on company's strategy on the operational level are needed. The above is possible thanks to proper training of middle-level management. These managers cannot be afraid of lack of acceptance of their activities from their superiors in the situation when immediate effects of their actions are not impressive or at least visible. Acceptance or actually support for this type of activities, when managers (but not line workers) realise an initiative with a delayed benefit is possible when competences of the managers (employees) enable assuming their efficiency. One more factor is necessary: the organisational culture conducive to activeness and innovativeness oriented towards continuous improvement.

2.4 Situation 4 – Employing a New Worker

It is a typical situation associated with rotation of employment, and the change is associated with the necessity to accept a new person for work (Fig. 4).

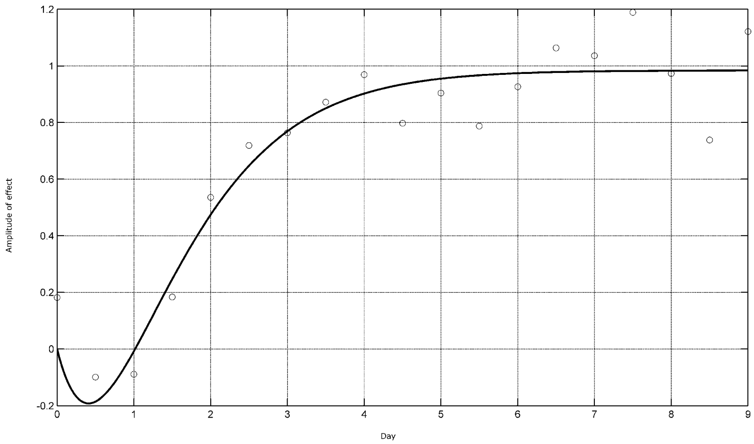

Fig. 4. Reaction to employing a new worker, manual acquisition.

Two situations are possible: 1. creating a new work post, 2. employing a person to fill a vacant post after a dismissed worker. If the worker at the new post will perform the tasks associated with the analysed area of organisation, the influence of the event on the effectiveness of this area can be also observed. The above is the result of the necessity of social, organisational and technical adjustment of both the elements, which will cause a minor drop in the efficiency of the studied subsystem and relatively quick increase of the effect up to the required level.

The second case concerns employing a person to replace a previous worker. In such situation a short-term drop of the system effectiveness can be observed with a quick return to the required efficiency.

2.5 Situation 5 – Informing a Worker About a Disciplinary Penalty

Besides an immediate influence of the situation (a very short period equal to the time needed to communicate the news), the penalty does not influence an individual (a worker or a group of persons). A reaction after the exposition depends on the ability to counteract and accumulate as well as to delay acting. It is important to realise that the situation itself is not about penalty as such, it is only about communicating the information. Due to the character and type of the situation it is difficult to separate the influence of the information itself from the role of the penalty. How to be convinced that the behaviour of the worker after having received the news is the effect of dynamic reaction to an impulse and not to a long-term and onerous influence of the penalty itself? Upon learning about the penalty, the worker reacts spontaneously, under the influence of emotions. In the studied cases the time of this emotional reaction varied between a few dozen minutes to a single shift. Reactions of workers and their comments on fulfilling their work tasks were under observation. The workers stated that spontaneous behaviour had been replaced by a rational approach just after the time necessary to rethink the circumstances and to exchange thoughts with colleagues or family. They declared that this was the time they needed to get over the situation. After that time the stage of reaction to penalty started [9].

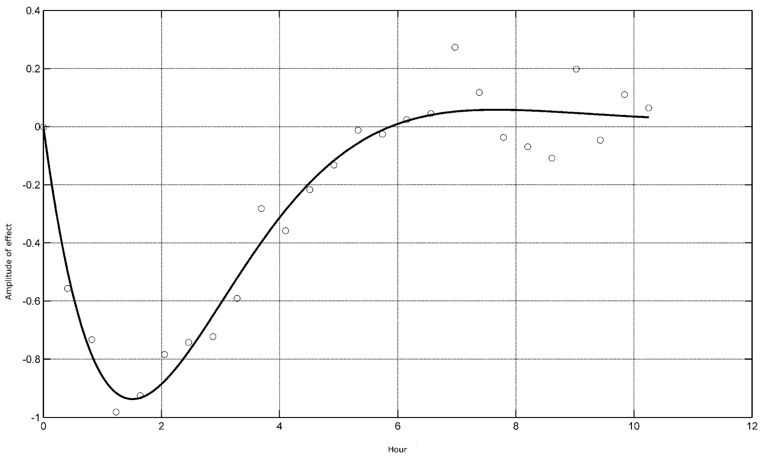

Fig. 5. Reaction of a worker to information about penalty, automatic acquisition

Observation of behaviour in response to the situation enables enriching the dynamics of the object with parameters responsible for fast courses. Yet such observation is highly difficult to perform because it is hardly possible to register parameters of reaction to this type of extortion. The accepted methods of data acquisition consist in developing registers of efficiency, performed by the workers themselves or by observers. In some cases, data can be collected by automated database systems. In case of an impulse it is difficult to achieve the will to cooperate on the part of a person who acts under the influence of emotions and can be prone to aggressive behaviour. Only non-participating observations and automatic acquisition can be used in this case. Yet it has to be remembered that for most extortions the observed parameters are work efficiency parameters, whereas dynamic analysis of observations and data can be used in case of other extortions.

The workers who received information about penalty ostentatiously demonstrated lowering their efficiency (23% of cases) or, as a result of annoyance, they unconsciously lowered the efficiency of their work (Fig. 5: vertical axis represents the change in efficiency). After the above period, in which information about punishment had dominating influence on the worker's behaviour, the worker's performance returned to the state from before the information acquisition. Usually also the period of reaction to penalty began at that time.

3 Summary

Influencing an element of an organisation with an intension to accelerate achievement of the assumed effect causes formation of resistance to this activity. The more stress is put on achieving the objective, the stronger the reaction. This phenomenon is known in the theory of management as Le Chatelier "equilibrium law", third Newton's law of motion or the rule of compensatory feedback in systematic terms.

The first reaction after initiating changes was often to pose questions usually associated with fears and anxiety about the course and the aim of the change. The workers also question the intentions of those to whom they pose their questions: are their responses comprehensive and true? do the initiators have honest intentions and do they know what is about to happen? Most often people form their own opinions about what will or should happen. They expect the questions and the received responses to provide argumentation to support their own conclusions. True character of certain judgements is assumed, and their credibility is aimed to be confirmed.

Also, questions appear that are formulated to confirm the assurance of support and fair play rules. In the situation when the turn of events cannot be changed, the sense of just treatment is valuable. Organisations that are aware of their authority and abide by the rule of honest approach to processes of changes are able to realise much deeper changes with greater success than the others.

Also tension in expectation of changes, manifested by accelerating negative consequences for workers, is a negative phenomenon. Workers, being afraid of problems connected with realisation of change (especially if in the past they personally experienced the consequences of e.g. being fired from work, transfer to another position, deterioration of condition), demonstrate activity in preventing such consequences by continuous looking around in search of better working conditions or another job. Their engagement in realisation of tasks is low due to the fact that they treat their working place as temporary. They take action only in the situation of a general threat to them as individuals.

Hiding is another negative attitude of workers towards change. The workers perform their job in such a way that they avoid being noticed. They follow instructions, realise tasks but first of all with the purpose to realise their own private aims. If under a threat, such persons demonstrate intense professional activity in order to keep their job. During implementation of changes the "hiding" persons manifest no resistance, they eagerly subject themselves to the process, but often with the intention to secretly sabotage the process of changes. Opinions of such persons are always accordant with the general trend. They never stand up for anything. This attitude is particularly dangerous because it causes weakening of managers' vigilance in face of a significant threat during changes. Especially that failure of change realisation may come unexpected.

The best attitude of workers towards changes seems to be expectant one with a will to cooperate. Of course, the real motivations of a person enthusiastically approaching changes are also important. Therefore, it is worth observing workers before deciding that their positive attitude towards changes is a true guarantee of success.

References

1. Maslyk-Musial, E.: Organizations in Motion: Change Management Strategies. Oficyna Ekonomiczna, Kraków (2003)
2. Mikolajczyk, Z.: Managing the Change Process in Organizations. Gornoslaska Wyzsza Szkola Handlowa, Krakow (2003)
3. Wisniewski, Z.: Implementation of changes - methodology based on the dynamic properties of the organization. In: Trocki, M. (ed.) Nowoczesne Zarządzanie – Koncepcje i Instrumenty, pp. 147–153. Oficyna Wydawnicza Szkoly Glownej Handlowej, Warszawa (2006)
4. Wisniewski, Z.: Modeling of production systems based on their dynamic properties. In: Knosala, R. (ed.) Komputerowo zintegrowane zarządzanie, pp. 482–488. Oficyna Wydawnicza Polskiego Towarzystwa Zarządzania Produkcja, Opole (2007)
5. Wisniewski, Z.: A computer system for recording the effects of implementing changes. In: Knosala, R. (ed.) Komputerowo zintegrowane zarządzanie, pp. 478–481. Oficyna Wydawnicza Polskiego Towarzystwa Zarządzania Produkcja, Opole (2007)
6. Wisniewski, Z.: The use of process capacity parameters to control the implementation of changes. In: Lachiewicz, S. (ed.) Zarządzanie rozwojem organizacji, pp. 220–225. Wydawnictwo Politechniki Lodzkiej, Lodz (2007)
7. Wisniewski, Z.: Implementing Changes in the Organization. Dynamic Approach. Wydawnictwo Politechniki Lodzkiej, Lodz (2010)
8. Brodny, J., Alszer, S., Krystek, J., Tutak, M.: Availability analysis of selected mining machinery. Arch. Control Sci. **27**(2), 197–209 (2017)
9. Polak-Sopinska, A.: Workplace Adjustments for people with disabilities. A case study of a research company. Part I – barriers for people with disabilities. In: Trzcielinski, S. (ed.) Advances in Ergonomics of Manufacturing: Managing the Enterprise of the Future, AHFE 2017. Advances in Intelligent Systems and Computing, vol. 606, pp. 335–347. Springer, Cham (2018)

The Concept of Teaching Modeling and Simulation of Manufacturing Systems

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Abstract. The paper describes advantages of teaching and application of modeling manufacturing systems. Two paradigms of modeling: Discrete Event (DE) and System Dynamics (SD) are briefly presented and compared. A few possibilities of teaching these approaches worldwide are presented. Furthermore, a combined way of teaching these two methods, with a focus on the modeling and simulating selected basic processes of manufacturing systems, is proposed in briefly described exercises. The concept provides division of this method depending on student's education level.

Keywords: Discrete Event · System Dynamics
Modeling manufacturing systems · Teaching

1 Introduction

In real world occur a lot of problems we would like to avoid or at least to minimalize their results. Although we can imagine most of them, we are not able to predict the impact on the system which is our point of interests. Usually it is expensive or impossible to examine the real systems for such possibilities. Modeling is a far easier, quicker way to simulate, allows to validate and verify systems before their implementation and after that. In manufacturing systems it is particularly important, because of their common complexity and high costs of any disruptions or disturbances [1].

Modeling and computer simulating, creating Digital Factory are inseparable from the concept of Industry 4.0, which should be implemented using a variety of possibilities. Therefore, these skills should be taught showing a wide range of methods. A significant factor in implementing and using of new generations, especially in age of rapid changes in technology is lifelong learning. It is relevant to Logistics 4.0 and Industry 4.0 due to their interrelationship. Teaching about modern techniques transferring a part of work to the computer systems corresponds to market demand [2].

Important is not only simulating and planning production processes including exchange of real, current data, but also past data. Based on them, we are able to predict a future process execution, control running processes. To catch the problems or fails in running processes and to influence on them correctly they must be seen in the right time, precautions and corrections have to be done.

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A core of Industry 4.0 application is using an optimization potential that comes out from mixed ways of production data processing. The innovation derives from connection more data sources, which were before used separately and from processes improvement – both technical or organizational. The technology is seen as an instrument to goals achievement and has to accommodate to given boundary conditions. The Industry 4.0 provides three key aspects: intelligent (smart) products, intelligent (smart; collaborative) machines and augmented (assisting) operator. These paradigms can be widely implemented in technologies without risk of changing added value by any application [3].

If our knowledge about met systems and their simulating is sufficient enough, the built models aim their tasks.

2 Models and Systems

According to Borshchev and Filippov [1] there are generally two types of models: analytical and simulation. Outputs of analytical models depends on inputs calculated, based on functions which can be written in a spreadsheet. Simulation models are seen as sets of rules. They define the behavior of system with the passing time, taking into consideration the initializing state. During simulation the states of model are changed over time – adequately in discrete or continuous approach [1].

To model the system properly we should correctly evaluate its character. The main, but not exclusive system classifications [4] provide seven levels of distinction (consecutive): static or dynamic, time-varying or time-invariant, linear or nonlinear, continuous-state or discrete-state, time-driven or event-driven, deterministic or stochastic and discrete-time or continuous-time. Figure 1 presents they division with focus on placing Discrete Event Systems.

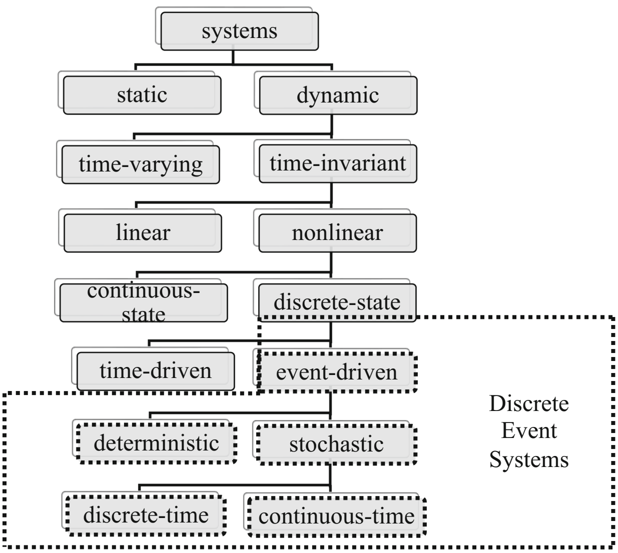

Fig. 1. Placing Discrete Event Systems in systems classification [4].

However, it would be really convenient to classify a real system as only one type of system, it is almost impossible. Most of them represent hybrid systems. For an example may we use collecting in packets (containers) some fluid or gas material supplied by a pipeline or a gas pipeline. There are two subsystems, each a bit different. First, the (gas) pipeline is time-driven. The material flows all the time, until a flow control gets a signal, that the desired level in a container is reached and starts when a container is ready to be filled. Second, a queue with buffer of containers is event-driven. The containers are filled and changed when an event occurs – the container is full. Therefore, we can use Discrete Event Systems as an abstraction of hybrid systems, but the converse is also true. Hybrid systems can be used to describe more complex Discrete Event Systems. Cassandras and Lafortune [4] show in an example the Internet as an Discrete Event System, where packets of information are waiting in queue to be sent out. In case when there is a huge amount of packets, we can treat them as a fluid flow and their movement described using differential equations – typical for time-driven flow dynamics. A moment, when a buffer will be empty of filled, would be playing a role of event.

Two chosen and both widespread approaches of systems modeling and simulation are Discrete Event and System Dynamics. The main differences between these paradigms are shown in Fig. 2.

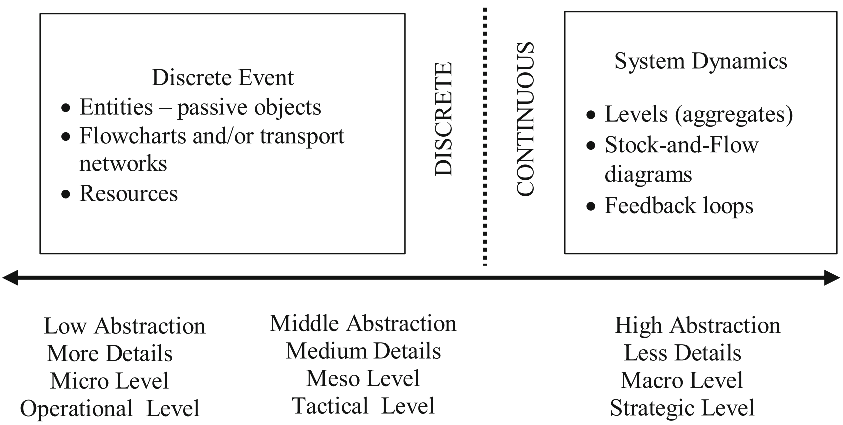

Fig. 2. Abstraction level differences between Discrete Event and System Dynamics paradigms [1].

2.1 Discrete Event

This type of modeling is based on the idea of entities, changing their state in discrete points of time. Due to entities interrelationship the state change of one entity can influence over the state of another ones. That implicate the new state of the whole system. An entity of the model represents a component of the investigated system which has to be described precisely enough in order to impact on the system behavior. The modeler should remember about the aim of the simulation study while defining each entity. These basic elements have their own characteristics, values describing current state and by what it is affected. A sequence of actions of an entity during some time period can model its behavior. A set of activities like this can result in a state change and when it occurs, an event emerges. Therefore, events and activities have to be modeled precisely and accurately to the goals of the investigation. The event-oriented simulation can be seen as a consecutive set of snapshots of the model state. First snapshot is special due to the fact that it is presenting an initializing state. This state is always defined by the modeler and any following state is based on it. Furthermore, we distinguish exogenous and endogenous events, depending on placing its origins. When they are outside model's boundaries we call them exogenous, when inside – endogenous [5]. Examples of plenty use Discrete Event modeling are shown in [6–9].

2.2 System Dynamics

System Dynamics is a theory of system structures and interactions between its components. This approach helps to model and analyze complex systems, their dynamic behavior, based on loops and a concept of feedback. There are three types of basic elements: stock (level) element (state variable), flow element, auxiliary variables and constants. With them the modeler is able to build in an easy way a model of a system described by differential equations. This approach allows to aggregate materials and as long the model is using them, it is not possible to distinguish items in it. The modeler has also to think about possible global dependencies existing in a system [1, 9]. In System Dynamics models the main variable is time. However this type of modeling is considered mostly as based on continuous type, can be used in models with the discrete concept of time [10]. Applications of System Dynamics paradigms in manufacturing processes are presented in publications: e.g., [11–15].

2.3 Available Tools

There are a lot of tools dedicated for modeling Discrete Event Systems like Enterprise Dynamics, Arena, FlexSim, Tecnomatix Plant Simulation, Witness Horizon. The choice is often based on a price, needs and preferences of the user (3D models, Virtual Reality view, training), already bought license in a company and its partners. These arguments are true by every kind of software. It is worth underlining, that in the automotive industry in Germany for the simulation of material flows for production planning and logistics, the most common tool is Tecnomatix Plant Simulation [16].

System Dynamics tools are commercial with trial or PLE versions and freeware, e.g., Vensim, PowerSim, iThink, Wolfram SystemModeler (System Dynamics library). Interesting fact is, that in course "Introduction to System Dynamics" at Massachusetts Institute of Technology, where the idea of System Dynamics "came" from, is used VensimPLE [17].

There are not many tools, where both approaches are available. ExtendSim offers different modules, i.e. Continuous Process (CP) for System Dynamics, Advanced Technology (AT) – adds Discrete Event modeling, Suite – adds 3D modeling. Interesting tool is AnyLogic, which as the only one joins not only System Dynamics and Discrete Event, but also Agent Based method in one software.

3 Teaching Methods

In general, we should realize, that the area, topics and methods of teaching in some purpose depend on demand of the nearest surroundings. A course of study should be flexible, changed according to forecasts and requirements. On the other hand, it should teach about something more, giving a possibility to take a look at the big picture of some issues. The authors made short research in teaching about these two approaches. The investigation was based on public accessible information, which is seen by the interested students *in spe*. They can use this information to decide about a place to study, looking for modern and interesting courses.

3.1 Worldwide Tendency

Starting with a teaching of System Dynamics we should look at Massachusetts Institute of Technology. There are two consecutive courses at graduate level, each is a half-semester course, 3 h weekly of lectures and 1,5 h of exercises. The main target of this subject are students interested in Management, Organizational Behavior, Systems Engineering. The first course is an introduction. Students learn using VensimPLE, starting from building a model. They find how to define a problem and model purpose using casual loop diagrams, mapping the stock and flow structure of systems. Further the dynamics of stocks and flows is presented and how to link a feedback with their structure. That is a good point to start analyze a system and create robust policies. Next step of this lecture are business case studies. The second course provides work on modeled systems, which need to be changed to create proper models of some cases. Also, in this course some real systems in various domains are presented. Interesting is a way of grading. Some tasks have to be done in small teams and at the end evaluated are not only tasks by lecturer, but also a student by his teammates [17, 18].

Another considered course of System Dynamics is in Swiss Federal Institute of Technology in Zurich. This course takes 3 h weekly (2 of lecture and 1 of exercises) and is structured along three main tasks, which are finding solutions, implementing and controlling them. Students use Vensim, propably PLE version. The course presents complex systems as a thing which cannot be simplified but can be seen by systems-oriented management in another way. The problem-solving cycle allows to find solutions of proper structured problems. Students learn how to implement solutions and to identify the critical path, know the role of quality control and small changes in systems. During the course are shown examples from biology, management (including production systems) and economics (combined with analytical models). Grading is based on individual homework and final exam based on theory and exercises [19].

This approach is quite often use in researches of many fields, but not so many Universities provide the whole courses about it. Interesting fact is, that University of Bergen gives an opportunity to study 2 years to obtain the degree Master of Philosophy in System Dynamics [20].

Because the idea and implementation of Industry 4.0 is well-developed in Germany, the authors focused on teaching Discrete Event Simulation and Discrete Simulation in this country. There are many courses, the differentiation between them is significant, but we can assume, that the number of hours of lectures and exercises is about 50 per semester. There are purely theoretical courses and theory mixed with practice and modeling. The range of topics contains concepts like Petri Nets, Statecharts, Timed Models, Stochastic Timed Automata, Markov Chains, Queueing Models, Bayesian Networks, Dynamics Bayesian Networks. Other lectures give short overview of techniques of Discrete Event models and simulations – first the basics of statistics, how to build models, how to insert empirical data to model, how to plan and execute simulation experiments, how to evaluate their results. During more practical courses often used software are Arena and Plant Simulation. Additional topics are, e.g., extended knowledge of probability distribution, process and production industry application examples. To get a grade, students usually have to write an exam and take part in exercises. The exam can include theoretical issues and a problem to solve with use of simulation software.

3.2 In Poland

In most of Polish Universities of Technology, where in authors' investigation focus was on courses and studies connected with production engineering and management, the Discrete Event modeling is taught and practiced. There was found only one University of Technology, where the System Dynamics approach could be concerned, but it is clear, that used is R – a programming language and free software environment for statistic computing and graphics. R needs using a programming skill. On the same course are only presented another software environments, much easier to understand and use, like Vensim, iThink, etc. Taking into account that software, courses about them and System Dynamics are generally hard to find. However, this approach is mentioned or used in various publications.

Definitely easier to find are courses with application Discrete Event simulation tools. The most popular are Tecnomatix Plant Simulation and FlexSim. Less common are Arena, Enterprise Dynamics, AnyLogic, Witness Horizon. Although the choice of software is important, it often depends on University's budget. What is not sensitive to it, is a course of study. It can be organized in different ways. The main idea of many courses is to present some theoretical background and examples of practical use or, at least, only the software. We can see courses at level ending at Bachelor of Engineering/Science and Master of Science. The courses are held as lectures, exercises and laboratories in different number of hours, e.g.: 30 h of lectures and 15 of exercises; 30 h of lectures, 30 h of exercises and 15 h in laboratory; just 15 h in laboratory; 15 h of lectures, 30 h of exercises and 15 h in laboratory; 15 h of lectures, 10 h of exercises and 10 h in laboratory. There is no particular rule.

Courses at lower degree include definitions and classifications of productions processes, systems, their elements and parameters, surroundings. Students learn about the identification and analysis of material flow, types of workplaces and how to design and organize them (regarding the most optimal number of it, a production method, an available space, positions, ergonomics, safety, time and processes). Taught are the basics of transport and warehouse logistics, documentation. On the other hand, students obtain the knowledge on informatics systems development, their elements and stages of their implementation. They know why different classes of software are applied, principles and stages of the application in concrete example. More expanded courses provide the basic knowledge of production like definitions of production cycle, push and pull systems, material flow, etc. It explains a concept of production analytical forecasts, how to classify and make them. The elements of JIT, Lean Production, MRP, MRP II, ERP, other methods and techniques have been introduced. Additionally, wastage, but also ergonomics, safety and occupational health, human factor are briefly mentioned.

The exercises can be held without computers, and then analytical solutions and methods mentioned at lecture are practiced (e.g., calculating and time reduction of production cycles, drawing their graphs, calculating productive capacity and production plan).

Finally, in laboratory students have a possibility to practice with a software. The basic form of courses predicts to show the elements of the software and how to implement them correctly. Students grades depends on correctness of exercises done during hours spent with lecturer. Another way is to show students how to build few models of fundamental processes and change parameters. Further they will obtain skills of building model and choice correct values of its values. A lecturer should teach how a change of any element can influence or redefine the whole system. To get a grade, students have to model some real system. On other course students learn also more about detailed modeling production hall, workplaces, material flow, etc., but also have to suggest proper documentation for this system (process maps, flowcharts, layouts).

Significant is, that less courses about Discrete Event are on studies on level Master of Science. The programs provide less hours with this type of software but give an opportunity to see parallel also the idea of expert system, learn about business management through playing a simulation game, simulation using Monte Carlo method, System Dynamics and programming language. It should be emphasized, that those courses are quite rare. What they have in common is assumption, that students already have the basic knowledge about production and need to see it in a context, learn new tools.

4 The Concept

The need of continuous improvement quality of teaching regards changes. The authors propose the concept of teaching containing both Discrete Event and System Dynamics paradigms as worth to know. Presented overview showed that both approaches are usable at different levels of management, systems simulations. As Discrete Event Systems represent lowest levels (of abstraction, aggregation etc.), can be helpful to manage daily works of manufacturing systems, to solve some engineering problems in production processes, changing layouts, calculate basic values of current and eventually future planned actions, sequences, processes executions. System Dynamics is a method useful for more complex problems on higher levels but can be also implemented to simulate processes in production systems, but not so detailed.

These arguments decide, that the teaching of both approaches should be in modules. The first module would be held on Bachelor's or Engineer's Degree level of studies. That should be taught on possible ending semester to avoid a problem of explaining fundamental terms of production systems. That course would be based on learning a tool, ways to implement a simple manufacturing system with a few consecutive workplaces. It is because often students end their education on this level, but basic knowledge about using Discrete Event modeling software would be desired. A short accompanying lecture should teach about basics of statistics, probability distributions, implementing empirical data to model, planning and executing simulation experiments and analyze the results. Graded would be a short individual project – to model a system described by data provided by teacher.

On the second level of studies – Master of Science, there would be two courses. First would teach more about Discrete Event modeling. There would be much more theory including e.g., Petri Nets, Bayesian Networks, Markov Chains, Monte Carlo method. In laboratory students would make a project in small group of two-three – implementing more complex model – a real production system they know, of some small company or a part of production line, its analyze and optimization. Grades should be based on exam and project. The choice of enterprise's size is relevant to Polish economy and a difficulty level for students. Small enterprises make up 3% of all companies in Poland, 96% are micro enterprises. 15,6 thousand (0,8%) are medium enterprises and 3,4 thousand (0,2%) are large ones [21]. Lot of companies are usually not suitable, because they do not represent manufacturing industry, are not interested due to their manufacturing methods or are companies not typical for Industry 4.0.

On the same level should be taught System Dynamics in focus on production processes. The lecture should present the main assumptions, introduce Systems Thinking. Further, in laboratory model elements should be described, simple models would be implemented and related not only to manufacturing, to show a chosen software. Then, a teacher should go to analyze and optimization of models, regarding to different factors of manufacturing and production, explain how to prepare experiments. In the same time on the lecture would be presented case studies. Graded would be exercises in laboratory and a short exam of lecture.

The choice of software plays a secondary role. The main idea is to teach an approach, a specific mindset, then a tool. Recommend would be to use only one software for both paradigms. Due to expensive licenses, on the other hand would be better to use free software, like VensimPLE which is sufficient for an academic purpose and buy another software for Discrete Event simulations. Because this second software should be popular in a commercial use, in industry, a good idea would be Tecnomatix Plant Simulation. The choice of software should combine a reasonable price with giving possibilities, as training courses also.

The important fact is, that the human factor, ergonomic issue is usually not mentioned in teaching of modeling. When it is omitted, cannot influence on the model, where a human plays some role. When a human is not taken into account, we cannot say, how he - as an element - affects the whole system. That means, the course should be also oriented on human capabilities and fatigue. Above all, to highlight new tasks, which human will be performing and are waiting to be modeled for the first time.

5 Conclusion

The authors of paper are of the opinion, the teaching modeling and simulating of manufacturing systems should contain both Discrete Event and System Dynamics approaches. Discrete Event paradigms is nowadays popular in modeling manufacturing processes by many companies, but System Dynamics, used in Industrial, Economics and many other fields, allows to operate on aggregate variables and see the problems more global.

Students should be taught from the very beginning to pay a special attention to modeling the interaction human – machine giving proper time and delays for every action. Although the fourth industry generation means less interactions between them, it does not mean that all the humans will be replaced by robots. The cooperation with them and controlling them will be a must. It is possible, that soon we will have to considerate another factor, related to this cooperation, as we used to in our models. The continuous following and analyzing of actual processes is essential to verify an efficiency of a model.

References

1. Borshchev, A., Filippov, A.: From system dynamics and discrete event to practical agent based modeling: reasons, techniques, tools. In: The 22nd International Conference of the System Dynamics Society, Oxford, England (2004)
2. Wrobel-Lachowska, M., Wisniewski, Z., Polak-Sopinska, A.: The role of the lifelong learning in logistics 4.0. In: Andre, T. (ed.) Advances in Human Factors in Training, Education, and Learning Sciences, pp. 402–409. Springer International Publishing, Cham (2018)
3. Bauernhansl, T., ten Hompel, M., Vogel-Heuser, B.: Industrie 4.0 in Produktion, Automatisierung und Logistik: Anwendung Technologien Migration. Springer Fachmedien Wiesbaden, Wiesbaden (2014)
4. Cassandras, C.G., Lafortune, S.: Introduction to discrete event systems (2008)
5. Ullrich, O., Lückerath, D.: An introduction to discrete-event modeling and simulation. Simul. Notes Eur. **27**(1), 9–16 (2017)
6. Seewaldt, M., Nagel, J., Geckler, D., Bracht, U.: Energy-oriented material flow simulation as a contribution to automotive industry 4.0. Simul. Notes Eur. **27**(2), 61–66 (2017)
7. Rabe, M., Deininger, M.: Discrete event simulation of modular production system models using Petri Nets. In: Rabe, M., Clausen, U. (eds.) Simulation in Production and Logistics, pp. 387–396. Fraunhofer IRB Verlag, Stuttgart (2015)
8. Völker, S., Schmidt, P.-M.: Simulationsbasierte Optimierung von Produktions- und Logistiksystemen mit Tecnomatix Plant Simulation. In: Zülch, G., Stock, P. (eds.) Intergrationsaspekte der Simulation: Technik, Organisation und Personal, pp. 93–100. KIT Scientific Publishing, Karlsruhe (2010)
9. Bouloiz, H., Garbolino, E., Tkiouat, M.: Modeling of an organizational environment by system dynamics and fuzzy logic. Open J. Saf. Sci. Technol. **3**, 96–104 (2013)
10. Ossimitz, G., Mrotzek, M.: The basics of system dynamics: discrete vs. continuous modelling of time. In: Proceedings of the 26th International Conference of the System Dynamics Society, Athens, Greece, pp. 2416–2423 (2008)

11. Orcun, S., Uzsoy, R., Kempf, K.: Using system dynamics simulations to compare capacity models for production planning. In: Proceedings - Winter Simulation Conference, pp. 1855–1862 (2006)
12. Georgiadis, P., Michaloudis, C.: Real-time production planning and control system for job-shop manufacturing: a system dynamics analysis. Eur. J. Oper. Res. **216**, 94–104 (2012)
13. Özbayrak, M., Papadopoulou, T.C., Akgun, M.: Systems dynamics modelling of a manufacturing supply chain system. Simul. Model. Pract. Theory **15**, 1338–1355 (2007)
14. Piewthongngam, K., Vijitnopparat, P., Pathumnakul, S., Chumpatong, S., Duangjinda, M.: System dynamics modelling of an integrated pig production supply chain. Biosyst. Eng. **127**, 24–40 (2014)
15. Kiyani, B., Shahnazari Shahrezaei, P., Kazemipoor, H., Fallah, M.: Dynamic modeling to determine production strategies in order to maximize net present worth in small and medium size companies. J. Ind. Eng. Int. **6**, 51–64 (2010)
16. Wenzel, S., Peter, T.: Simulation zur Sicherstellung der Wettbewerbsfähigkeit - Ergebnisse einer Umfrage zur Simulation in Produktion und Logistik. In: Friedewald, A., Lödding, H. (eds.) Produzieren in Deutschland - Wettbewerbsfähigkeit im 21. Jahrhundert, pp. 243–264. Gito, Berlin (2013)
17. MIT - Introduction to System Dynamics – Syllabus. https://ocw.mit.edu/courses/sloan-school-of-management/15-871-introduction-to-system-dynamics-fall-2013/syllabus
18. MIT - System Dynamics II – Syllabus. https://ocw.mit.edu/courses/sloan-school-of-management/15-872-system-dynamics-ii-fall-2013/syllabus/
19. ETH Zürich - Vorlesungsverzeichnis - Systems Dynamics and Complexity. http://www.vvz.ethz.ch/Vorlesungsverzeichnis/lerneinheit.view?semkez=2017W&ansicht=KATALOGDATEN&lerneinheitId=116926&lang=de
20. University of Bergen - Master's Programme in System Dynamics. http://www.uib.no/en/studyprogramme/MASV-SYSDY
21. Raport o stanie sektora małych i średnich przedsiębiorstw w Polsce (2017)

Methods for Assessing the Effectiveness of Language Learning – A Comparative Study

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Abstract. The aim of this paper is to provide an overview of the existing tools and methods used to measure the effectiveness of language education in language centres (LCs). LCs present various approaches to both curriculum design and management systems. If a closer link is to be sought between the teaching methods, the institutional management and the effectiveness of the education process, a proper classification and evaluation of the verification methods used in quality language teaching is needed. The analysis is based on literature review and includes methods employed for the assessment of language ability.

This study is a part of an ongoing project that is aimed at finding correlations between the teaching and the management methods and efficiency.

Keywords: Language assessment instruments · Summative assessment Formative assessment · Effectiveness · Validity · Reliability · Practicality

1 Introduction

In the context of quality management in Language Centres (LC), much attention has been given to language assessment as indicative of the school's overall performance and areas for possible improvement. Language schools are held accountable for the provision of educational services that meet students' personal needs, the needs of prospective employers or the job market in general, and at the same time are in line with national and the widely-recognized standards such as the Common European Framework of Reference (CEFR). Large-scale assessments offer reliable data on the school's efficiency, they influence decisions on educational policy, infrastructural investments, curriculum design, relocation of human resources and sometimes even enforce changes in teaching practices. Alternative performance-based assessments, while primarily designed to identify the learners' needs and to monitor their learning from classroom-based activities, can also provide valuable information for educators and managers at school levels. Such integration of traditional and alternative, or summative and formative assessments has long been desired by many assessment experts [1–4].

The purpose of this paper is to present current trends in language assessment by reviewing some of the traditional and modern assessment instruments and showing how they can be combined effectively. First, a short description of the concepts of summative and formative assessment is given. Then, we explore the common challenges encountered

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when developing assessment strategies and the key factors in the evaluation of assessment instruments. Various tools are later described in brief, followed by a detailed analysis of the advantages and limitations offered by each with reference to the aforementioned criteria. Finally, a few practical guidelines are listed as to how and why teachers should use multiple combinations of assessments.

2 Basic Principles in Formative and Summative Assessment

The distinction between formative and summative assessment was first posed by Scriven [5], who suggested that early on in the process of language instruction teachers can collect data on their students' performance in order to identify learning needs and adapt their teaching accordingly. Also, by providing students with instant feedback they can more actively engage the learners in classroom activities and shape their future learning. Formative assessment is now described in literature as ongoing or continuous assessment, the primary goal of which is to help students develop. It encompasses all kinds of classroom interactions, short quizzes and progress test, interviews, student presentations and projects, written assignments, to name just a few [6]. Students are further encouraged to monitor their own work by reflecting upon the learning goals established by the teacher and trying to identify the gaps.

Summative assessment, by contrast, is aimed at measuring or summarizing student competencies and skills gained in a particular course. Typically, it is conducted at the end of an instructional unit and takes the form of final tests, general proficiency exams (large-scale standards-based tests) or end-of-year marks. It is the assessment of learning and is usually used for administrative purposes such as promotion, certification or admission to higher levels.

Undoubtedly, both approaches to language assessment offer several advantages as well as have some limitations (these will be examined in Sect. 5), therefore researchers call for a greater integration of the two. While many teachers agree that formative assessment methods can greatly improve the quality of language teaching, they voice concerns about the feasibility of implementing them into regular practice as there are too often some logistical roadblocks such as large or mixed ability classes, over-packed curricula, or ever-increasing course documentation requirements [7].

3 Challenges in Language Assessment

Assessing language learners presents several challenges. One such challenge is the fact that learners are never evaluated just for the sake of establishing what they know of or how well they speak a foreign language. Assessment is always conducted for a particular reason. There might be some administrative purposes: to place learners in an appropriate instructional level, to qualify them to participate in academic or mobility programs, to promote them to higher positions or to demonstrate that they comply with national accountability requirements. It is also used as part of the program to diagnose the learner's goals and needs, to motivate learners to advance to higher levels by offering instant feedback. It can also serve as evidence of their progress or measure the effectiveness of teaching methods and curricula. Assessment can also be research-oriented [8]. One instrument can, on average, perform only several functions, as there is a major distinction between proficiency tests (used commonly for administrative purposes), where learners' general linguistic competence is measured, and achievement tests that assess what learning outcomes have been achieved from what was taught in a given instructional period.

Another important issue is the diversity of learners. Not only are there great divergences between their cognitive styles and even personalities, but there are also differences in their educational and cultural backgrounds. Added to this is their age, foreign-language aptitude and personal motivations for learning languages as well as one-time performance factors such as fatigue or stress. The list is by no means exhaustive, and as a consequence, despite the large number of instruments, none seems to be a panacea to all teacher and learner needs in all situations. Current practice and theory suggest that a good compromise might be to apply a combination of different formats in order to assess language abilities.

To determine which instruments could be most effective, each should be subjected to a closer inspection, which would attempt to answer the common questions language educators and learners pose:

- Is it easily aligned with the course content or the learning objectives of the area being assessed?
- Are the results reliable?
- How much time and effort does it require both from the learner's and the teacher's perspective?
- Is it cost-efficient?
- Does it reflect the language used in the real world?

These are the reference points for the measuring the effectiveness of an assessment; it must be valid, reliable, practical and appropriate.

4 Assessment Validity, Reliability, Practicality and Appropriateness

The general concept of validity was traditionally defined as "the degree to which a test measures what it claims, or purports, to be measuring" (p. 231) [9]. It can be further discussed by focusing on four categories: content, construct, criterion-related and face validity. Content validity is the extent to which the assessment instrument is relevant and representative of the content or learning objectives of the course that it is supposed to measure. To define construct validity, the notion of a 'construct' needs to be explained first. A construct is a theoretical model, attribute or hypothesis that attempts to explain phenomena observed or perceived by human brain. 'Proficiency' or 'intercultural competence' are examples of constructs. Construct validity is the demonstration that the instrument used for assessment measures the construct it claims to be measuring. Criterion-related validity, in broad terms, is demonstrated by comparing the results of an assessment with some other external measures of the same objectives. Another important factor, particularly from a learner's perspective, is face validity.

Face validity is based on subjective judgements made by students (and teachers alike) on whether a test or any other assessment procedure looks fair, relevant and useful.

Whenever a learner is assessed by a teacher or through a test, they would expect that if they went through the whole procedure again, under similar circumstances, the results would be the same. This replicability of results is known as reliability [10]. A number of factors need to be taken into consideration when developing a reliable instrument, such as the clarity of instructions, the number and type of tasks, the administration procedures, the people who do the scoring, the assessment criteria and the conditions under which the test is administered. With response to those challenges Komorowska [2] offers a practical set of questions to the developers of the assessment:

- Is the time limit appropriate? Is the test not too long or not too short?
- Is the test not too short to make judgements about a learner's progress?
- Are all instructions and tasks clear and unambiguous?
- Are the assessment criteria clear and known to the assessors?
- Are the assessors equipped with the key? Does it include a list of possible answers for open questions or sample texts?
- Are there any standardisation or calibration workshops for the assessors?

Before enrolling in a language course, much information is available on the course content, the level of difficulty or the number of hours in class. Usually, little is known about how much of that time will be spent on tracking the learners' progress as this has become part and parcel of any language instruction [11]. Assessment is seen as practical when it does not require excessive workload and effort on the part of the teacher and the associated costs are still reasonable. A practical instrument should be economical in terms of time and money. In lager groups, for example, a speaking assessment based on individual long turns (20 min for learner presentation plus scoring) seems rather unrealistic. Similarly, colour prints, recording studios or computer labs, they all generate extra costs, which can easily be avoided with the use of alternative assessment tools.

The quality of assessment is judged upon yet another factor, namely to what extent it resembles real-life situations, how authentic the language input and output is, is it *appropriate*? With current trends towards formative assessment, teaching is inextricably linked with giving feedback on the learner performance in the course of their educational path. A test can be used both for teacher control and learner development, where test takers are expected to demonstrate their skills and knowledge appropriately, i.e. using natural, authentic language in role-played scenarios rather than reciting memorised phrases for classroom situations [12–14].

5 A Brief Overview of Assessment Instruments

Assessment offers a wide array of instruments, many of which go beyond paper and pencil. This study looks only at a sample of traditional and alternative assessment tools, as collating a comprehensive list is not within the scope of this paper. Each instrument is briefly characterized, followed with a more detailed analysis of its effectiveness, determined against the aforementioned criteria: validity, reliability and practicality (see Table 2). Authenticity or appropriateness of assessment relies largely in a test writer's personal choices and as such is not the subject of this review.

1. *Tests*

Researchers have proposed various criteria for test classification. The simplest distinction is made with reference to their form. There are:

- paper and pencil tests
- electronic tests
- oral tests

With respect to what is being tested, two types are listed:

- language elements tests (e.g. vocabulary tests, grammar tests, phonology and spelling tests)
- skills tests (reading skills, listening skills, speaking skills, writing skills or integrated skills tests)

Tests can be used for a number of purposes and while there is a general split into norm-referenced tests (measuring the performance of one group of test takers against another group of test takers) and criterion-referenced tests (measuring examinees' performance against a set of pre-defined criteria or standards), the following taxonomy gained popularity among teachers:

- proficiency tests, measure a person's overall linguistic competence; these are usually large-scale commercially available tests with examples including, CASAS, TOEFL or Cambridge exams
- achievement tests, which evaluate a learner's understanding of specific material defined in the syllabus
- placement tests, used to determine a new student's academic ability in order to assign him to a group at a particular level; similar to a proficiency test, though much shorter and simplistic
- diagnostic tests, which identify areas to work on
- prognostic tests, which try to predict a learner's ability to complete a course or take an exam

For the purpose of this paper, however, another test discrimination will be used, which is presented below:

1a. *Large-scale standards-based tests*

They measure a broad band of competencies, not exclusive to one particular curriculum. These are typically the commercially available proficiency tests, such as TOEFL or TOEIC, CASAS or Cambridge exams. They are summative and norm-referenced, administered to large populations.

1b. *Teacher-developed tests*

Most of them are achievement tests that can be used both for summative and formative assessment. Quizzes are excluded from this group since tests are viewed here as covering more material than a quiz and being more formal. They are rich in formats and task types. They can test specific language points and integrated skills such as reading and writing or listening and writing [15]. Rather lengthy.

2. *Scales*

Scales are used to assess learners' 'global skills' towards the end of a course with reference to widely recognized standards such as the Common European Framework of Reference (CEFR) or American Council on the Teaching of Foreign Languages (ACTFL). The teacher gives descriptive grades in all skills (e.g. B1 + in writing, B2 in speaking) on the basis of their own observations of the learners' contribution in class, homework, test scores, etc.

3. *Checklists*

Checklists can include language points and 'can do' statements. Individual learners are assessed across a list (can be quite lengthy) of 'can do' descriptors reflecting the course content. Checklists can also be used for learner self-assessment.

4. *Quizzes*

These are short and informal versions of a test and they are usually administered without prior notice. They can be a quick check on how well the latest material has been learned by individuals, be it vocabulary lists or grammar points. Learners receive immediate feedback on their progress.

5. *Portfolios*

Portfolios are collections of learners' individual work and can include samples of written assignments, reviews of the books read, learners' reflections on their progress in form of 'can-do' statements, notes or grade reports from oral interviews, scores on standardised tests and data from any other form of performance-based assessments.

6. *Oral interviews*

An interview is a face-to-face exchange between one or two test takers and a test administrator, following a pre-established protocol of questions and directives. Interviews vary in length depending on the purpose and context.

7. *Oral presentations*

A presentation is an example of extensive speaking assessment, popular in academic and professional contexts. Students can be asked to present a variety of topics including product development, a service, a method, marketing plan or present the results of a project or study.

8. *Written assignments*

Assessment of student writing performance should occur at successive stages of the course, inside and outside of the classroom. As it can be used for a variety of purposes, it should come in multiple formats. Table 1 depicts an abundant collection of written genres.

Table 1. Genres of writing

1.	**Academic Writing**
	papers and general subject reports essays, compositions academically focused journals short-answer test responses technical reports (e.g., lab reports) theses, dissertations
2.	**Job-related writing**
	messages (e.g., phone messages) letters/emails memos (e.g., interoffice) reports (e.g., job evaluations, project reports) schedules, labels, signs advertisements, announcements manuals
3.	**Personal writing**
	letters, emails, greeting cards, invitations messages, notes calendar entries, shopping lists, reminders financial documents (e.g. checks, tax forms, loan applications) forms, questionnaires, medical reports, immigration documents diaries, personal journals fiction (e.g., short stories, poetry)

Source: Reprinted from [12], p.219

9. *Self- and peer-assessment*

This typically takes place soon after a student's performance (direct) or after a longer stretch of time, e.g. after a unit, module or whole term (indirect). The learner is asked to monitor him- or herself and render some kind of evaluation. For this purpose, they might fill out a checklist or a questionnaire, use some Internet-based self-correcting quizzes and tests or construct short tests themselves and get engaged in more open-ended assessments such as journals [16, 17].

The tools listed above (1a–9) are further examined in Table 2 in terms of their effectiveness, by studying their possible benefits and shortcomings with respect to three selected features: assessment validity, i.e. to what extent it measures what it is supposed to measure, assessment reliability, i.e. to what extent it can be trusted and assessment practicality, i.e. to what extent it is easy to administer and score [18, 19]. Other factors such as creativity potential, attractiveness to the learner, authenticity, etc. are excluded from this study since they are very much dependent on personal preferences and choices of the teacher and the student [20].

Table 2. The merits and pitfalls of language assessment instruments

Tools	Validity	Reliability	Practicality
1a	+ can be used for a number of purposes; + have construct validity − may not capture the learners' progress over short periods of instructional time,	+ highly reliable as there are rigorous test development and validity procedures; + require minimal training on the part of the teacher	+ easy to administer to groups; + speed in scoring; often computerised or marked with pre-programmed scanners − costly; usually commercially available − removed from the instruction time − delayed feedback
1b	+ can be tailored to match institutional objectives + broad focus; + offering a wide variety of items	− require training on item writing	+ much cheaper than large-scale tests + easy to administer − costly in time and effort
2	− difficult to define which skills or language items are assessed, too 'global' − low face validity	− very unreliable − impressionistic	+ simple, quick, non-bureaucratic
3	+ can easily be linked to the syllabus; + key course objectives can be assessed	− teachers can lack detailed knowledge of the performance of individual students	− time-consuming for the teacher; − quite bureaucratic
4	+ timely and relevant; + can train learners for the test; + provide useful feedback; − narrow focus; − limited variety of items	+ easy to score and evaluate (no complex procedures nor grading criteria)	+ short preparation time on the part of the teacher + brief, ease of administration (do not consume teaching time)
5	+ content and face validity (multiple components of the curriculum can be assessed) + can be used for administrative and instructional purposes	+ increased student reliability (provide numerous samples in different forms of student performance − low scoring reliability (difficult to set up reliable and valid grading criteria)	+ economical in terms of student time and effort − time-consuming and require much effort on the part of the teacher − delayed feedback
6	+ content validity (questions designed to elicit desired language points) + face validity due to their individualised nature + can be used for a number of purposes, both administrative and instructional − fail to meet formal accountability requirements	− poor scoring reliability; risk of running impressionistic − requires standardisation training on the part of the teacher	+ timely feedback − time-consuming: when done in class consumes instruction time, when done outside of class –expensive

(*continued*)

Table 2. (*continued*)

7	+ probably most effective way of assessing extensive speaking − narrow focus	− inter-rater reliability must be addressed − prone to decreased student reliability (public speaking can be extremely stressful)	− time consuming and labour intensive both for learners and teachers − difficult to administer in large groups − can be costly (proper equipment needed, cost of coloured print of slides)
8	+ content validity, can be aligned with course objectives + face validity − criterion-related reliability (difficult to define what they are meant to test: spelling, grammatical accuracy, paragraph construction, logical development, topical vocabulary?)	− specific sets of criteria need to be developed − inter-rater reliability must be addressed	− time consuming and labour intensive both for learners and teachers, especially at higher levels − delayed results
9	+ content validity if course objectives and task types clearly communicated to the learners + face validity, especially with checklists and questionnaires if used on regular basis	− great threat of subjectivity − students might apply different standards to their peers	± moderate; can be quick to administer, with immediate feedback (checklists and self-correcting quizzes) but much more demanding with respect to journals and student-generated tests

Source: Own elaboration.

6 Concluding Remarks

Effective assessment is a daunting challenge and more than often we have to compromise on the needs of the key stakeholders: the learners, the teachers and the school's management [21]. It has been agreed that no tool proves effective for all players at all times. Instruments should be selected based on evidence in the literature, the particular purpose of the assessment (the why and what to measure) and student feedback produced in the course of learning [22]. Teachers should employ multiple measures to capture a more complete picture of learner achievement. They should set appropriate tasks and procedures that would match the learning goals of a given program and engage learners in their progression of skills. Practical aspects cannot be neglected here. Adequate resources need to be provided, therefore issues of staff turnover and training, costs of materials, infrastructure and timeframes should be carefully considered [23, 24]. In this paper, major advantages along with some limitations of the selected assessments have been pinpointed, which will, hopefully, serve as a guide to teachers and academic managers in the process of selecting appropriate evaluation methods for their learners.

References

1. Bailey, K.: Learning About Language Assessment: Dilemmas, Decisions, and Directions. In: Freeman, D. (ed.) Teacher Source Series. Heinle, Boston (1998)
2. Komorowska, H.: Assessment of Skills in Language Learning. Fraszka Edukacyjna, Warszawa (2002)
3. Looney, J.: Integrating Formative and Summative Assessment. OECD Publishing, Paris (2011)
4. Marshall, B.: Testing English: Formative and Summative Approaches to English Assessment. Continuum, London (2011)
5. Scriven, M.: The Methodology of Evaluation. AERA Monograph Series on Evaluation, vol. 1, pp. 39-83 (1967)
6. Shepard, L.A.: Classroom assessment. In Brennan, R.L. (ed.) Educational Measurement, 4th edn., pp. 623–646. American Council on Education/Praege Publishers, Westport, CT (2006)
7. OECD: Formative Assessment: Improving Learning in Secondary Classrooms, OECD, Paris (2005)
8. Jacobs, H.: Testing ESL Composition. Newbury House Publishers, Rowley (1981)
9. Brown, J.D.: Testing in Language Programs. Prentice Hall Regents, Upper Saddle River (1996)
10. Crocker, L., Algina, J.: Introduction to Classical and Modern Test Theory. Holt, Rinehart and Winston, Orlando (1986)
11. Bachman, L.F., Palmer, A.: Language Testing in Practice. OUP, Oxford (1996)
12. Brown, H.D.: Language Assessment: Principles and Classroom Practice. Prentice Hall Hertfordshire, UK (2003)
13. Cohen, A.D.: Assessing Language Ability in the Classroom. Heinle, Boston (1994)
14. Coombe, C., Hubley, N.: Assessment Practices. TESOL Case Studies Series. TESOL Publications (2003)
15. Coombe, C., Folse. K., Hubley. N.: A Practical Guide to Assessing English Language Learners. University of Michigan Press, Ann Arbor (2007)
16. Fulcher, G.: Practical Language Testing. Hodder Education, London (2010)
17. Fulcher, G., Davidson, F.: Language Testing and Assessment. An Advanced Resource Book. Oxon OX14 4RN (2007)
18. Harris, M., McCann, P.: Assessment. Heinemann Publishers, Oxford (1994)
19. Kunnan, A.: Validation in Language Assessment. Taylor and Francis, Hoboken (2013)
20. Luoma, S.: Assessing Speaking. Cambridge University Press, Cambridge (2004)
21. North, B.: The CEFR in Practice. Cambridge University Press, Cambridge (2015)
22. O'Sullivan, B.: Notes on Assessing Speaking. http://www.lrc.cornell.edu/events/past/2008-2009/papers08/osull1.pdf
23. University of Cambridge ESOL Examinations: Using the CEFR: Principles of Good Practice October 2011. http://www.cambridgeenglish.org/images/126011-using-cefr-principles-of-good-practice.pdf
24. Weir, C.: Understanding and Developing Language Tests. Prentice Hall, Hertfordshire (1993)

A Look at the Ergonomic Situation of the Bakery Industry in the City of Quito, Ecuador

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Abstract. Bread and flour products are one of the main foods in the daily diet of people of Quito, Ecuador. In the city of Quito, there are 1500 legally established bakeries, but the number is much greater and unknown by informal businesses; it is estimated that there are at least 6000 direct jobs impacted, now the fundamental problem in the sector is the lack of technologies. Objective: The objective of this study was to determine the level of risk of workers exposed to ergonomic hazards during bread preparation. Materials and methods: A cross-sectional and descriptive study using application-specific methods for postural loading such as the Rapid Entire Body Assessment (REBA) and for repetitive OCRA (Occupational Repetitive Actions) Check List to three of the five largest bakeries in the city of Quito, in all the tasks of kneading, cooking and stowing of the bread in the oven were evaluated. Results: The results of the above methods were analyzed and high levels of risk were found to be intervened immediately Conclusions: There are no studies related to the topic of baking and ergonomics in Quito, so new evaluations should be carried out to complement the results found in a special way in small or artisanal bakeries and can support the improvement of working conditions, in addition to being able to determine the prevalence of musculoskeletal damages of labor origin in the field evaluated.

Keywords: Occupational hazards · Ergonomics · Food industry

1 Introduction

The daily diet of the Andean cities of Ecuador consists mainly of bread, a staple food that is part of the traditional diet. It is usually prepared by baking a dough, made mainly with cereal flour, salt and water and products where the flour is located, in the city of Quito - Capital of the Republic of Ecuador- it is one of the main places to find bakeries, is one of the main family subsistence businesses at SMEs level. There are 1500 bakeries legally established in the metropolitan district, but the number is much higher and actually unknown because these businesses are informal and subsistence in nature; It is estimated that there are at least 6000 direct jobs, in legally constituted bakeries,

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now the fundamental problem in the sector is the lack of technology; and that is the reason that the process is still done by hand [1].

Working in the food industry is a heavy work and its workers suffer injuries and pains in various parts of the body, generating economic costs in compensation and absenteeism. In the process of bread making, there are multiple tasks that involve the exposure of workers to occupational hazards, including ergonomic risks, because people have to adopt unsuitable postures, performing tasks characterized by cycles and also generally manipulate heavy loads [2].

Most bakeries do not have safety and health practices in their production processes and only the large bakery chains have practices that are governed by the health and safety regulations registered by the Ministry of Labor.

The objective of this study was to determine the level of risk of workers exposed to ergonomic hazards during the preparation of bread. The tasks that are usually carried out in standing postures with the adoption of unsuitable postures, with many movements and also horizontal and vertical displacements, with high repetitiveness and highly demanding physical efforts.

The stages of the process evaluated are the following:

- Kneading. - Action of Work that consist the dough trying to mix all its ingredients, it can be manual or assisted by a machine.
- Arming action. - Shape a piece of dough to prepare a bread of the characteristic or shape that is desired.
- Stowing the bread in the oven. - Place the bread on the baking sheets.

Exposed workers have not been subjected to occupational medical evaluations, so there are no official occupational medical data, although a high percentage refers musculoskeletal pain mainly to the shoulders, neck, wrist and lower back. Despite being a legal requirement to implement a Health Surveillance Program for all workers for all companies in the country, this type of activity is not done in practice because there are no regular controls established by the authorities.

2 Materials and Methods

The present work concentrated on studying and evaluating the large and semi-industrialized bakeries of the city of Quito, Ecuador. Three of the five largest bread makers in the city of Quito were visited and evaluated within the mentioned category. kneading tasks, assembly and stowage of the bread in the oven.

The working population consists of male and female workers, in an age range between 18 to 45 years, with an average work experience of 5 years in the different bakeries, the criterion of 5 years of experience was chosen because to the skill acquired and the stereotype of movements of the evaluated tasks, on the part of the workers made them a homogenous population in terms of their competencies and therefore are comparable to each other.

The bakery plants were visited at the invitation of those which wanted to evaluate their tasks ergonomically and to know their level of risk. The plants of the three companies were visited twice between August and December 2016, on the first visit, the tasks were determined and areas where the information would be collected. During the second visit, we proceeded to shoot and take photographs of the process as well as the production data referring to units produced, weight of the loads handled as well as the age of the workers. [3]

For the evaluation, specific methods for postural loading were used, such as the Rapid Entire Body Assessment REBA [4] and for repetitiveness the OCRA [5] (Occupational Repetitive Actions) Check the List and for its analysis.

The REBA Method allows to establish the level of risk resulting from the adoption of forced postures of the different body segments such as neck, trunk, legs, arm, forearm and wrists taking into account additional factors such as the application of force, the type of grip and the mode of activity performed.

The OCRA Method makes it possible to determine the risk by repetitiveness derived from various components such as frequency, strength, posture, duration and recovery in the execution of work tasks [6].

The ERGO-IBV software was used and then an analysis of the data was carried out in an electronic spreadsheet. The data collection was carried out in routine labor activities and the evaluations were carried out in all the aforementioned bakery tasks in three semi-industrial bakeries of the city of Quito during 2016.

3 Results

The results of the specific evaluations of forced postures in baking are:

In the kneading stage in which the worker mixes the ingredients of the dough in the proportions suitable for making the bread, a medium level of risk with a REBA final score of 4 to 6 is evidenced, mainly due to the neck asymmetry, arms and trunk.

In the assembly phase in which the worker shapes the dough so that the bread making process is completed, an average risk level could be determined with a final REBA score of 5 to 11, due to the asymmetry of the forearms, wrists, trunk, arms, and neck.

In the stowage position of the baking trays an average risk level was established with a final REBA score of 4 to 6, due to the asymmetry of forearms, wrists, neck, trunk and arms (Fig. 1).

REBA score right side									
Place	REBA level	Risk level	Action level	REBA level	Risk level	Action level	REBA level	Risk level	Action level
Stages	Kneading			Arming action			Stowing the bread in the oven		
Bakery A	4	Medium	Necessary	5	Medium	Necessary	5	Medium	Necessary
Bakery B	5	Medium	Necessary	5	Medium	Necessary	4	Medium	Necessary
Bakery C	6	Medium	Necessary	9	High	ecessary Soo	5	Medium	Necessary
REBA score left side									
Bakery A	4	Medium	Necessary	5	Medium	Necessary	4	Medium	Necessary
Bakery B	4	Medium	Necessary	5	Medium	Necessary	4	Medium	Necessary
Bakery C	6	Medium	Necessary	11	Very High	ecessary Nov	6	Medium	Necessary

Fig. 1. REBA final score in each activity per extremity

In all the tasks of the production, 18 work positions were evaluated, which presented an average risk level of 88.9% and a high risk level of 11.1%; being the body segments most affected trunk, neck, arms and wrists. Some positions are due to the requirement of the task and others due to poor design of some work areas (Fig. 2).

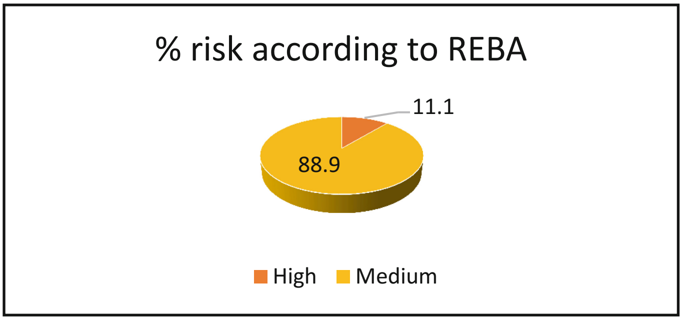

Fig. 2. Level of risk in percentages by forced postures

The results of the specific evaluations of repetitiveness in baking tasks are:

In the kneading phase in which the worker mixes the ingredients of the dough in the proper proportions for the preparation of bread, a final OCRA Check List score of 4.28 to 11 was established, due to insufficient recovery, influence of asymmetric postures.

In the assembly phase in which the worker shapes the dough to complete the bread making process, a final OCRA Check List score of 17 to 28.12 was established due to insufficient recovery, high frequency, application of force, and influence of asymmetric postures (Fig. 3).

In the stowage station of the baking trays, a final OCRA Checklist score of 10 to 31.6 was established due to insufficient recovery, high frequency, application of force, and influence of asymmetric postures.

OCRA score right side						
Place	REBA level	Risk level	REBA level	Risk level	REBA level	Risk level
Stages	Kneading		Arming action		Stowing the bread in the oven	
Bakery A	11	Low	21	Medium	12,62	Medium
Bakery B	8,5	Low	28,12	High	29,53	High
Bakery C	9,5	Low	25,31	High	31,6	High
OCRA score left side						
Bakery A	7	Acceptable	17	Medium	10	Slight
Bakery B	8,5	Slight	28,12	High	29,53	High
Bakery C	4,28	Slight	25,31	High	14,7	Medium

Fig. 3. Level of Risk OCRA in each stage per extremity

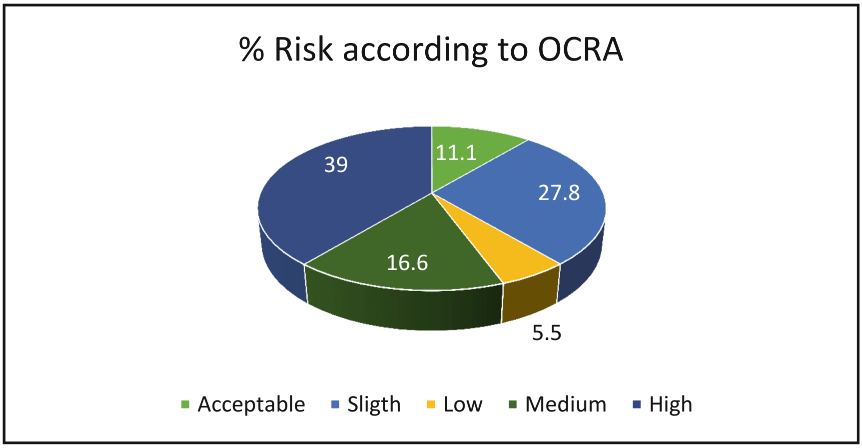

Fig. 4. Percentage of the Risk Level due to repetitive movements.

Regarding repetitiveness, three activities were evaluated that presented an average risk level of 16.6%, and a high risk of 39%, being the factors that most affect the risk the lack of breaks, a high frequency of work, and an excessive overload on the muscular structure of the wrists (Fig. 4).

4 Conclusions

These results show that ergonomic load levels are not acceptable in the bakery activities in the city of Quito, so short-term research programs on safety and health in the bakery industry must be integrated in the short term in order to improve their work environments and prevent musculoskeletal disorders.

The most critical level of risk is found in the activities that involve the use of repetitive movements, these are tasks that must be modified by the excessive work rate, immediately due to the high risk they demand from workers.

Regarding the postural load, the risk is also high, either due to bad postural habits, bad job designs, or, all factors that lead to conclude that exposed workers are potential candidates to develop musculoskeletal disorders in extremities superior and back to medium and long term.

This study wants to highlight the need to implement technological and/or organizational improvements in the bakery jobs, technical actions such as the redesign of jobs or the implementation of machines as well as organizational such as the training of workers; the implementation of a health surveillance program that can detect any discomfort or damage that workers may suffer early should also be given immediately.

The lack of anthropometric dimensions of the Ecuadorian population makes it difficult to import machines according to Ecuadorian measures, leading to the design of inadequate jobs.

There are no studies related to the issue of baking and ergonomics in Quito, so new evaluations should be carried out that can complement the results found in small or artisan bread makers. Also, they can support the improvement of working conditions, as well as being able to determine the prevalence of musculoskeletal injuries of occupational origins in the evaluated field.

The study should be extended to work conditions and also to the evolution of workers' health in bakeries.

References

1. Dudeja, P.: Food safety in the 21st century. Public Health Perspect., 269–280 (2017)
2. Botti, L.: Improving Ergonomics in the Meat Industry: A Case Study of an Italian Ham Processing Company. IFAC-Papers OnLine, pp. 598–603 (2015)
3. Neupane, S.: A four-year follow-up study of physical working conditions and perceived mental and physical strain among food industry workers. Appl. Ergonomics **45**(3), 586–591 (2014)
4. Hignett, S.: REBA: Rapid Entire Body Assessment. Appl. Ergonomics **31**, 201–205 (2000)
5. Occhipinti, E.: OCRA: a concise index for the assessment of exposure to repetitive motions of the upper limbs. Ergonomics **41**(9), 1290–1311 (1998)
6. ISO 11228-3:2007. Ergonomics. Manual handling. Part 3: Handling of low loads at high frequency (2007)
7. Gadotti, T.: The importance of ergonomics in the process of improving working conditions in the food service industry: factors involved in the development of musculoskeletal symptoms. Biblioteca de Saúde Pública, Hig. aliment, **29**(242/243), 26–30 (2015)

The Case for Paternity Leave in Ghana: Imperatives and Implications for Gender Parity

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Abstract. The aim of this paper is to make a persuasive case for the provision of paid paternity leave for fathers in Ghana by describing several benefits of paternity leave to the family and the business as a whole. The paper examines the arguments for paternity leave through series of literature review, the position of law on paid paternity leave in Ghana and its implications for gender parity. The paper also presents examples of countries that have ratified the ILO conventions on paternity leave provisions and enshrined them in their country-specific legal regulatory frameworks. Given the diverse benefits of paid paternity leave around the world, the need for paternity leave has become a necessity if not obligatory. The paper makes a strong case for expedite action on the amendment of Ghana's labour law to incorporate at least five days paid leave for fathers in relation to childbirth in Ghana.

Keywords: Paternity leave · Family and business case · Legislation Regulation · Gender parity · Ghana

1 Introduction

"What is sauce for the goose is sauce for the gander" – Proverb

The need for paternity leave has become a necessity if not obligatory in Ghana. Both theoretical and empirical evidence posit that fathers' involvement in the upbringing of the child is imperative [1]. According to the International Labour Organization [2] report on maternity and paternity at work, recognition of men's right to paternity leave will help break down traditional social attitudes, resulting in greater equality for both men and women at work and then at home. Access to paternity leave is thus imperative for an employee's ability to reconcile both work and family life.

Although the media in Ghana has in recent times debated the nuances and need for or against paternity leave, it has gained less attention within the academic circles. Thus, this paper seeks to arouse the interest of researchers and practitioners to address the issue once and for all, given its enormous benefits evident in countries that have ratified

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the ILO convention on provisions of paid paternity leave. Paid maternity leave is said to be crucial in protecting the health and economic security of women and their children. Since *what is sauce for the goose is sauce for the gander,* the paper also posits that paid paternity is crucial in safeguarding the health and economic security of men and their family, hence, the need for paid paternity leave to be provided for in the regulations governing work and employment-related issues in Ghana.

This paper serves as a clarion call for the lawmakers in Ghana to make provisions for paid paternity leave just as maternity leave is protected by law [3] and the Labour Act [4] as "*what's sauce for the goose is sauce for the gander*". This paper thus sets out to present arguments for paternity leave by focusing primarily on the family and business case for paternity leave. It further examines the position of the law on paternity leave in Ghana as well as its implications and imperatives for gender parity.

2 Arguments for Paternity Leave

2.1 Family Case for Paternity Leave

According to Harrington et al. [1], the significance of paternity and paternal leave to the family cannot be underestimated. In the United Kingdom (UK), paternity leave is said to be strongly linked to mother's wellbeing in the first trimester after birth [5]. Similar findings from Norway [6] and Sweden [7] point to the fact that paternity leave is also associated with a reduction in mothers' absence by 5 to 10% due to sickness and an increase in mothers' earnings by 6.7% respectively. Also, in France [8], paternity and paternal leave is associated with a reduction in depression among new mothers.

Notwithstanding the benefits of paternity leave, empirical evidence shows that fathers involvement is positively correlated with their children's overall life satisfaction and experience of less depression [9], less emotional and psychological distress [9, 10] and [11], greater sense of social competence and self-reported happiness [10, 12] as well as fewer anxiety symptoms and lower neuroticism [13]. Besides, paternal acceptance and nurturance is positively related to youths' self-reported psychological adjustment [14]. To this end, Ross and Broh [15] and Amato [16] stated that children of involved fathers are more likely to demonstrate greater internal locus of control, greater ability to take initiative, and use self-direction and control. Also, high levels of father involvement is said to be associated with increase in children's feelings of paternal acceptance, an element that plays a critical role in the development of self-concept and self-esteem [17, 18].

Regardless of the costs associated with paternity leave (e.g., decreased self-esteem, stress and increased work-family conflict), empirical evidence shows that paternity leave results in an overall satisfaction with parenthood whilst fathers' emotional attachment with their children has been reported to act as a buffer against work-related stressors [19, 20]. In conclusion, it appears paternity leave allows fathers to take-up family responsibilities and early interaction with their children and these are directly linked to successful child development [2].

2.2 Business Case for Paternity Leave

Attention to the business case for paternity leave has gained noticeable consideration. The OECD [21] observes that through paternity leave employers are able to motivate and increase productivity of existing workforce, increase workforce flexibility and attract and retain qualified employees. Hence, DeMott and Lynch [22] stressed that more employers today are making paternity leave available to male workers in some form, whereas leading employers are exploring possible ways to advance their current paternity leave policies.

Although several potential benefits of paternity and parental leave to the organisation have been highlighted in literature some scholars postulate that the top business motives for offering paternity leave include *sustaining competitive practice*, *talent retention*, *ensuring equity and fairness*, *providing new father/child bonding* and *becoming an employer of choice* [19, 20] and [22]. According to Boushey and Glynn [23], paid leave improves employee retention which saves employers money through reduced turnover costs. This is because research has shown that turnover cost an average of one-fifth of an employee's annual salary. Nevertheless, paid leave such as paternity leave reduces these turnover costs and encourages valuable workers to stay in the labour force and with the same employer [24].

Paid leave also increases worker productivity. For instance, Matos and Galinsky [25] highlighted that employers are aware that supportive programmes like paid paternity leave promotes the retention and recruitment of employees and finally increases worker productivity. According to Milkman and Appelbaum [26], nearly 90% of businesses surveyed on the effects of the California paid paternity leave programme said that the programme had positive effect on productivity. Again, paid leave improves employee loyalty and morale. Additionally, several New Jersey employers noted that state's paid paternity leave programme help reduce stress among employees and also improves morale among employees and their co-workers [27].

Another business case for paid leave is the fact that it allows smaller businesses to compete better with larger businesses. Small businesses often have difficulty matching more generous leave benefits offered by larger employers – potentially resulting in a hiring disadvantage. However, Appelbaum and Milkman [28] observed that although all employers reported positive outcomes, overall small and medium-sized businesses reported more positive outcomes than large businesses. Furthermore, in the work-family literature, the consequences of conflict are not only limited to individuals and their families but also the companies. In essence, the benefits of paternity leave trickles down to more happy family life and happy family life means more productive employees.

3 Paternity Leave in Ghana: The Position of the Law

The conversation on legislating paternity leave in Ghana is twofold: whether national legislation should provide for paternity leave in addition to maternity leave as well as the length of paternity leave that should be provided. The 1992 Constitution of Ghana and the Labour Act [4] make provisions for only maternity leave. For instance, Article

27(1) of the 1992 Constitution and Section 57 of the Labour Act [4] explicitly cater for paid maternity leave. Article 27(1) of the 1992 Constitution of Ghana is unambiguously clear when it stipulates that *“Special care shall be accorded to mothers during a reasonable period before and after childbirth; and during those periods, working mothers shall be accorded paid leave”* (p. 25). Similarly, Section 57(1) of the Labour Act [4] stipulates that *“A woman worker, on production of a medical certificate issued by a medical practitioner or a midwife indicating the expected date of her confinement, is entitled to a period of maternity leave of at least twelve weeks in addition to any period of annual leave she is entitled after her period of confinement”* (p. 18). Not only does the law grant a woman worker maternity leave, it makes further provision to protect the woman’s full remuneration and other benefits to which she is otherwise entitled (Section 57(2) of Act 651).

Even though the law does into explicitly deny or take away the right of a father to enjoy paternity leave upon the birth of his child, it does not grant any express right to such fathers. The law appears silent and thus give employers an option to grant its male employees paternity leave or not. It appears the express grant of such right to mothers and the silence of the law on that of fathers may constitute discrimination against fathers and my create an unequal opportunity for fathers whose presence at home, upon the birth of a child, may contribute immensely towards the growth and development of the child. Article 17 of the 1992 Constitution, without taking away the right of Parliament to enact laws to ensure the implementation of certain policies and protect certain interests provides for equality and freedom from discrimination. It states that all person shall be equal before the law and a person shall not be discriminated against on grounds of gender, race, colour, ethnic origin, religion, creed or social or economic status.

The extent that the 1992 Constitution guarantees protection against inequalities before the law, discrimination on the basis of gender amongst others, the silence on the rights of fathers to paternity leave, seems to be an oversight that must be corrected appropriately, as it does not seem to be in line with the spirit of the Constitution. Parliament could therefore under Article 17(4)(a) enact laws to fill this lacuna.

Keeping up with global trends on paternal and paternity leave, Ghana is in the process of providing fathers with paternity leave. For example, a memorandum attached to a bill entitled ‘*The Labour (Amendment) Act 2013*’ aimed at amending the Labour Act [4] proposes that fathers be provided five working days of paternity leave [29]. Expedite action is however required as there is currently no direct provision in any legislation in Ghana for paternity and paternal leave. Notwithstanding the statutory inadequacies in Ghana, some private and multinational organisations have made provisions for paternity leave for their male employees. Classic example is Databank Financial Services Limited which provides its male staff with five working days of paid paternity leave since the past decade [30]. According to Kunu [30], Nestle Ghana Limited also introduced paid paternity leave for its male employees to support breastfeeding of infants. This policy was implemented in 2012 where fathers were granted three days of paternity leave and subsequently increased to five days. Similarly, in 2005 Barclays Bank Ghana Limited implemented its paternity leave policy which permits its male workers to take a three-day period off duty [30].

Finally, Otoo et al. [31] reported that paternity leave provisions in Ghana are contained in the collective bargaining agreements (CBAs) of such sectors as health, education and mining. The researchers indicated that the health sector has the highest proportion (33.3%) of CBAs with paternity leave provision followed by education sector (9.1%) and the mining sector (7.7%). A typical provision for paternity leave reads as follows: *"male employees of [name of institution/organisation] shall enjoy five (5) working days paternity leave to support a legally registered wife who has given birth. This shall be applicable to a maximum of four (4) children and shall be upon demand by the employee"* [31].

4 Illustrative Cases of Paternity Leave Around the World

4.1 Europe, Asia and America

For virtually every developed country in the world, an appreciation of the importance of the birth or adoption of a child is acknowledged and supported through paid leave for mothers and fathers. European Union policy encourages men and women to share parental leave to balance work and family life, and promote gender equality in the labour market. According to Valdimarsdottir [32] and Arnason [33] cited in Haas and Rostgaard [34], parental leave policy-making in the Nordic countries (i.e., Sweden, Norway, Finland, Iceland, Denmark) stands out from other countries with respect to the emphasis laid on gender equality as an important rationale for the provision of parental leave benefits for fathers. For instance, Sweden, the first nation in the world to offer fathers paternity leave in 1974, granted fathers the right to take three of the six paid months of leave available to couples with the option to transfer their entitlement/right to mothers [34]. Despite France, United Kingdom, Poland and New Zealand providing fathers with 14 days of paternity leave, the ILO [2] report shows that the United States remains the only country with no national policy on paid leave for both mothers and fathers.

Additionally, Asian countries such as Bangladesh, Cambodia, Indonesia, Korea, Myanmar, Philippines and Singapore offer fathers paternity leave. For example, Indonesia and Korea offer 2 and 3 days paternity leave respectively, while Myanmar offers 6 days paternity leave with pay by the employer. On the other hand, the Philippines and Singapore offers 7 days paternity leave with 100% cash benefit. Likewise, in the case of Bangladesh and Cambodia, fathers are entitled to 10 days paternity leave period. However, the ILO [2] report shows that Saudi Arabia and Syria are the only nations in the Middle East that provide fathers' paternity leave. While Saudi Arabia offers one day paternity leave which is fully paid, Syria on the other hand provides 6 days of unpaid paternity leave. Finally, in Latin America and the Caribbean, only thirteen countries provide paid paternity leave. Fathers are entitled to two days of paternity leave in Argentina, Dominican Republic and Guatemala; three days in El Salvador, Paraguay and Uruguay; four days in Peru; and five days in Brazil and Chile. In other cases, countries like Bahamas, Colombia, Ecuador and Venezuela offer seven, eight, ten and fourteen days of paternity leave respectively [2] (Tables 1, 2 and 3).

Table 1. Leave provisions for fathers in relation to childbirth in some Latin America and Caribbean Countries

Country	Paternity leave provision
Argentina	Two days of paid paternity leave
Brazil	Five days of paid paternity leave
Chile	Five days of paid compulsory paternity leave
Ecuador	Ten days of paid paternity leave
Guatemala	Two days of paid leave on the birth of the child
Uruguay	Three days of paternity leave for private sector, ten days for civil servants
Venezuela	Fourteen days of paid paternity leave

Source: ILO Working Conditions Laws Database – Maternity Protection

Table 2. Leave provisions for fathers in relation to childbirth in Europe

Country	Paternity leave provision
Denmark	Two weeks of paid paternity leave
Estonia	Ten working days of paid paternity leave
Finland	54 working days of paid paternity leave
France	11 working days of paid paternity leave
Greece	Two days paid paternity leave
Hungary	Five days of paid paternity leave
Iceland	Three months of paid paternity leave
Norway	Two weeks of unpaid leave, but often covered by collective agreements, plus 14 weeks of parental leave reserved for fathers
Spain	15 consecutive days of paid paternity leave
Sweden	10 days of paid paternity leave, plus two months of paid parental leave reserved for each parent
United Kingdom	Two weeks of paid paternity leave

Source: ILO Working Conditions Laws Database – Maternity Protection.

Table 3. Leave provisions for fathers in relation to childbirth in Asia and Middle East

Country	Paternity leave provision
Bangladesh	Ten paid days a year of "casual leave"
Cambodia	Ten paid days of special leave for family events
Philippines	Seven days of paid paternity leave for married workers
Singapore	One week of paid leave
Saudi Arabia	One day of paid leave for childbirth
Syria	Six days of unpaid "emergency" leave

Source: ILO Working Conditions Laws Database – Maternity Protection.

4.2 Africa

The duration and compensation tied to paternity leave varies considerably from one African country to the other. Overall, twenty-nine (29) countries in Africa offer fathers' paternity leave [2]. For example, fathers are entitled to one day paternity leave in Tunisia and Mozambique, three days in Algeria, Mali, Morocco and South Africa, and 10 days in Benin, Burkina Faso, Cameroon, Chad, Cote d'Ivoire, Gabon, and Togo. Also, other countries like Kenya and Burundi offer fathers 14 and 15 days of paternity leave respectively. In a number of African countries too, no specific paternity leave policy exist, but there are more general short-term emergency leave or family leave which can be used by new fathers. This is the case for example in Libya where fathers can take three days of emergency leave for a compelling reason such as the birth of a new born baby. Nevertheless, for countries like Ghana, Egypt, Equatorial Guinea, Nigeria, Senegal, and Zimbabwe, national legislation does not provide for paternity leave [2] (Table 4).

Table 4. Leave provisions for fathers in relation to childbirth in some African Countries

Country	Paternity leave provision
Algeria	Three days of paid paternity leave
Djibouti	Three days of paid paternity leave (among 11 paid days for family events)
Kenya	Two weeks of paid paternity leave
Mali	Three days of leave for the birth of a child, paid by social insurance
Mauritius	Five continuous working days of paid paternity leave
Morocco	Three days paid paternity leave
Mozambique	One day of paid paternity leave immediately after delivery
South Africa	Three days of paid leave for family responsibilities
Togo	Up to ten days of paid leave for "family events directly related to the home"
Tunisia	One day of paternity leave (private sector); two days (public sector)

Source: ILO Working Conditions Laws Database – Maternity Protection.

5 Implications for Gender Parity

While several definitions of gender exist. One of such definitions widely cited is Haas and Rostgaard [34]. According to them, gender is psychological and social characteristics associated with being either male or female and entails the construction, negotiation and performance of masculine and feminine identities. Also, Coon [35] defines gender as socially constructed roles, behaviours, activities and attributes that a particular society considers appropriate for men and women. Arnason [33] observed that gender equality encompasses the development of a society where men and women have equal rights, duties and opportunities. The author further remarked that an important rationale for the establishment and development of parental leave benefits for fathers is simply gender equality. Furthermore, Janus [36] opined that the inclusion of both parents in child caring was thought to redress within-family imbalances in the distribution of unpaid care work and the desire to increase possibilities for more equal gendered labour market participation.

Indeed assessing gender equality of paternity leave is not an obvious process. Ferrarini [37] and O'Brien [38] examined the degree of gender equality on the basis of how non-transferable leave rights and benefits are granted to men and women on one hand; and the nature and incentives for male uptake on the other. From the perspective this approach, gender neutrality and the lack of a specific allocation of leave time to either parent would count as less gender-equal than a 50–50 division of leave time between the two parents. However, Ray [39] asserts that the reverse is true. Thus, any specific allocation of time to fathers is perceived as gender-specific, while neutrality and free use are not. In a similar manner, McDonald [40] opined that gender neutrality and open use of leave time is really a matter of choice with no impact on gender equality. Employers should consider it normal that fathers want to be given time off to care for their little babies. Until then fathers quotas are equivalent to positive actions geared towards supporting women's presence in the labour market.

Ghana is not homogenous and each community is highly influenced by the views of its leaders, traditions and religious doctrine [41]. Gender affects individuals in diverse ways. Issues of gender are present in employment, education, division of labour and violence. In terms of access to employment, inequalities between men and women are still common despite noticeable improvements. Gender discrimination in employment occurs through several factors such as unequal access to work and payment for equal work, unfair prerogatives in favour of men pertaining to access to leadership positions. The gender division of labour in Ghana is evident across the country. Traditionally, there are strong divides between work that is acceptable for women and men. For example, in rural and urban families, labour division remains largely unequal as household chores are exclusively the responsibility of women [41]. There have been a number of positive developments towards gender parity in Ghana, including an affirmative action policy for women's representation on public boards; government programmes to improve women's access to micro credit and the provision of paid maternity leave among others. Interestingly, the 1992 Constitution of Ghana enshrines the principle of equality between men and women and calls for the prohibition of discrimination on all fronts with the exception of paid leave for mothers and fathers for childcare purposes.

6 Conclusion

Global research has demonstrated benefits of paid paternity leave to both families and businesses including but not limited to increased well-being for the new mothers and becoming an employer of choice. Despite these benefits, many fathers in Ghana have difficulty making the needed time to bond with their children in the first year of their lives due to the absence of legal regulations for the provisions of paid paternity leave. This is the reason why most men fail to become active co-parents in the first few months of the children's lives. According to Harrington et al. [1], for three to six months, the mother develops a close bond with her child as well as the confidence and competence to become the primary caregiver with the father immediately casting in the role of a supporting actor. Given the colossal benefits of paid paternity leave outlined above, we call for an expedite action on the amendments of the labour acts to incorporate a stipulated number of leave days with pay for male workers when their spouses give birth since *what is sauce for the goose is sauce for the gander.* Also, all other stakeholders including employers should help enshrine paid paternity leave in the collective bargaining agreement (CBA) with employees since it is now a necessity rather than luxury.

References

1. Harrington, B., Van-Deusen, F., Fraone, J.S., Eddy, S., Haas, L.: The New Dad: Take Your Leave. Centre for Work and Family, Boston (2014)
2. International Labour Organization (ILO): Maternity and paternity at work: Law and practice across the world. ILO, Geneva (2014)
3. The 1992 Constitution of the Republic of Ghana. Government of Ghana. http://www.politicsresources.net
4. The Labour Act of Ghana. The Labour Act, 2003 (Act 651) (2003). http://www.nlcghana.org
5. Redshaw, M., Henderson, J.: Fathers' engagement in pregnancy and childbirth: evidence from a national survey. BMC Pregnancy Childbirth **13**, 1–15 (2013)
6. Bratberg, E., Naz, G.: Does paternity leave affect mothers' sickness absence? Working Papers in Economics, no. 06/09. University of Bergen (2009)
7. Johannson, E-A.: The effect of own and spousal parental leave on earnings. Working Paper. Institute of Labour Market Policy Evaluation, Uppsala (2010)
8. Séjourné, N., Vaslot, V., Beaumé, M., Goutaudier, N., Chabrol, H.: The impact of paternity leave and paternal involvement in child care on maternal postpartum depression. J. Repr. Inf. Psych. **8**, 1–10 (2012)
9. Formoso, D., Gonzales, N.A., Barrera, M., Dumka, L.E.: Interparental relations, maternal employment, and fathering in Mexican-American families. J. Marr. Fam. **69**, 26–39 (2007)
10. Flouri, E.: Fathering and Child Outcomes. Wiley, Chichester (2005)
11. Harris, K.M., Furstenberg, F.F., Marmer, J.K.: Paternal involvement with adolescents in intact families: the influence of fathers over the life course. Demography **35**, 201–216 (1998)
12. Dubowitz, H., Black, M.M., Cox, C.E., Kerr, M.A., Litrownik, A.J., Radhakrishna, A., English, D.J., Schneider, M.W., Runyan, D.K.: Father involvement and children's functioning at age 6 years: a multi-site study. Child Maltreatment **6**, 300–309 (2001)
13. Jorm, A.F., Dear, K.B.G., Rodgers, B., Christensen, H.: Interaction between mother's and father's affection as a risk factor for anxiety and depression symptoms: evidence for increased risk in adults who rate their father as having been more affectionate than their mother. Soc. Psychiatry Psychiatr. Epidemiol. **38**, 173–179 (2003)
14. Veneziano, R.A.: Perceived paternal and maternal acceptance and rural African American and European American youths' psychological adjustment. J. Marr. Fam. **1**, 123–132 (2000)
15. Ross, C.E., Broh, B.A.: The role of self-esteem and the sense of personal control in the academic achievement process. Soc. Educ. **73**, 270–284 (2000)
16. Amato, P.R.: Family processes and the competence of primary school children and adolescents. J. Youth Adolesc. **18**, 39–53 (1989)
17. Culp, R.E., Schadle, S., Robinson, L., Culp, A.M.: Relationships among paternal involvement and young children's perceived self-competence and behavioural problems. J. Child Fam. Stud. **9**, 27–38 (2000)

18. Deutsch, F.M., Servis, L.J., Payne, J.D.: Paternal participation in child care and its effects on children's self-esteem and attitudes toward gendered roles. J. Fam. Iss. **22**, 1000–1024 (2001)
19. Barnett, R.C., Marshall, N.L., Pleck, J.H.: Men's multiple roles and their relationship to men's psychological distress. J. Marr. Fam. **54**, 358–367 (1992)
20. Pleck, J.H., Masciadrelli, B.P.: Paternal involvement by U.S. residential fathers. In: Lamb, M.E. (ed.) The Role of the Father in Child Development, pp. 222–271. Wiley, New York (2004)
21. OECD: Babies and Bosses: Reconciling Work and Family Life, vol. 2. OECD, Austria (2003)
22. DeMott, S., Lynch, K.: Defining paternity leave: shifting roles, new responsibilities in the family and the workplace. Executive Briefing Series. Boston College Centre for Work and Family (2004)
23. Boushey, H., Glynn, S.: There are significant business costs to replacing employees. Centre for American Progress Publication, 16 November 2012. https://cdn.americanprogress.org
24. National Partnership for Women & Families: Paid family and medical leave: Good for business. Fact Sheet (2015)
25. Matos, K., Galinsky, E.: 2014 National Study of Employers. Families and Work Institute Publication (2014). http://familiesandwork.org
26. Milkman, R., Appelbaum, E.: Low-wage workers and paid family leave: the California experience. In: What Works for Workers? Public Policies and Innovative Strategies for Low-Wage Workers, p. 305. Russell Sage Foundation Publications, New York (2014)
27. Lerner, S., Appelbaum, E.: Business as usual: New Jersey employers' experiences with family leave insurance. Centre for Economic and Policy Research Publication, June 2014. http://www.cepr.net
28. Appelbaum, E., Milkman, R.: Paid family leave pays off in California. Harvard Business Review, 9 January 2011. http://blogs.hbr.org
29. Soko, D.: Fathers to enjoy paternity leave - but only for five days. Ghananation Blog, 3 August 2013. http://www.ghananation.com
30. Kunu, E.E.: Assessing the impact of perceived significance of paternity leave on organization outcomes. Project work, Department of Business Education, University of Education, Winneba (2016)
31. Otoo, N.K., Osei-Boateng, C., Asafu-Adjaye, P.: Our bargains: analysis of outcomes of collective bargaining in Ghana. Labour Research Institute, Report (2009)
32. Valdimarsdottir, F.R.: Nordic Experience with Parental Leave and Its Impact on Equality Between Women and Men. Nordic Council of Ministers, Copenhagen (2006)
33. Arnason, A.: Parental leave, care policies and gender equality in the Nordic countries. In: Signurdardoittir, E. (ed.) Parental Leave, Care Policies and Gender Equalities in Nordic Countries, pp. 13–16. Nordic Council of Ministers, Copenhagen (2010)
34. Haas, L., Rostgaard, T.: Fathers' rights to paid parental leave in the Nordic countries: consequences for the gendered division of leave. Community Work Fam. **12**, 177–195 (2011)
35. Coon, D. (ed.): Introduction to Psychology: Gateways to Mind and Behaviour. Wadsworth, Belmont (2001)
36. Janus, J.M.: Gender roles, leadership and public relationships. Master's Thesis, University of Missouri, Columbia (2008)
37. Ferrarini, T.: Parental Leave Institutions in Eighteen Post-War Welfare States. Swedish Institute for Social Research, Stockholm, Sweden (2003)
38. O'Brien, M.: Fathers, parental leave policies, and infant quality of life: international perspectives and policy impact. Ann. Am. Acad. Polit. Soc. Sci. **624**, 190–213 (2009)

39. Ray, R., Gornick, J.C., Schmitt, J.: Who cares? Assessing generosity and gender equality in parental leave policy designs in 21 countries. J. Eur. Soc. Pol. **20**, 196–216 (2010)
40. McDonald, P.: Social policy principles applied to reform of gender egalitarianism in parenthood and employment. In: Gornick, J.C., Meyer, M.K. (eds.) Gender Equality. Transforming Family Divisions of Labour, pp. 161–176. Verso, New York (2009)
41. Saraceno, C., Keck, W.: Towards an integrated approach for the analysis of gender equity in policies supporting paid work and care responsibilities. Demographic Res. **25**, 371–406 (2011)

Ergonomics in Reuse and Recycling of Solid Materials: Demand Analysis

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Abstract. Concern over the efficiency and productivity of the different productive chains induces cooperatives to continuously reassess their goals and methods in order to maximize its indicators. In the context of the study of the management of organizations, it is necessary to approach and evaluate factors that influence the survival of the cooperative. The economic sector that includes recycling cooperatives, in turn, becomes the target of negative analyses concerning the organization of work, health, safety, and ergonomics, with low indicators of efficiency and productivity. This study addresses the application of ergonomics, in different contexts, to a solid waste recycling and commercialization association located in the central region of Brazil. It is concluded that several aspects of the cooperative could be improved, requiring the participation of the workers in this process of change in order to improve postures, methods, and work dynamics.

Keywords: Human factors · Recycling of solid materials · Solidary economy

1 Introduction

With the need for workers to find new income sources, at the end of the 20th century other possibilities for work organization and arrangements by the working class have emerged in Brazil. In this context, the solidary economy, as a guide for the construction of self-management models in companies, has influenced the creation of cooperatives based on socialist concepts that encourage cooperativism. According to Freitas [1], it has also inspired transformation of productive relations offered by the accelerated development of capitalist productive "mode of production" forces.

With this approach, a cooperative of recyclable materials was created for the allocation of workers aiming at development through generating work and income with social inclusion.

Globalization of the economy has caused changes in the productive structure in the most diverse sectors and has also roused competitiveness between organizations. According to Tupy [2], there are growing efficiency and productivity concerns about the different productive chains. This induces firms to reassess their goals and methods for seeking to maximize such indicators.

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From an applied perspective, this study is important because it is the main step of a process that can lead to substantial savings of resources with gains in efficiency and productivity that are important for companies in competitive environments Farrel [3].

The economic sector, which includes recycling cooperatives, end up becoming a target of analysis about the relationship of work organization, health and safety, with indicators of efficiency and productivity. Thus, the level of organization for a cooperative directly influences achievement of the final productive results.

When defining activities and allocation of tasks as well as staff in their particular sectors, it is possible to standardize the separation process for the final product. In this case, it is the recycled material that ultimately generates income with its sale. Therefore, it develops knowledge about the productive process which is fundamental to the study of guidelines that encompass productivity in a dynamic work environment such as a recycling cooperative.

2 Analysis of the Work Organization

Organizations, companies or institutions consist of "non-human" resources such as physical, material, financial, technological, marketing and employees who work in conjunction with one another and assume certain functions with specific purposes. Chiavenato [4] notes execution of each task through designing an action plan, goals, transfer of resources and the formal structuring of activities.

According to Oliveira [5], an organizational structure is the set of responsibilities, competencies, communications and decisions of organizational units of a company. When the organizational structure is established in a proper way, it provides:

- Identification of the tasks required;
- Organization of functions and activities;
- Information, resources and work sectors.

When establishing the concepts of sector, tasks and activities in the organizational structure of the cooperative, it is possible to define and schedule production using the largest amount of resources available in addition to allocating staff. Additionally, maximum use of the workspace aims at increasing efficiency and maximize productivity.

As such, all the operations of the cooperative foster performance of tasks that generate profit which may then be classified and oriented in accordance with the sector, activity and task.

Regarding the production standards, the workday is from 08h00 min to 12h00 min and 13h00 min to 17h00 min from Monday to Friday. The activities are operational and consist of processing all the material collected manually.

With respect to the operative mode, cooperators perform all the functions of the productive process. There is substantial variability observed in these tasks as the speed of the production process that is not continuous, and the activities are manual of simple content. Silva [6, 7] observed this in a similar way as well.

The demand of time directly links to the demand of activities to be completed, and there is no enforcement of the amount to be produced in a given time period. The speed, cadence, and rhythm of activities are directly connected to the demand of the task flow with frequency and regularity for execution of activities. Thus, the control of production exists in an informal way from the demands passed by the leaders of the cooperative, but without sharp pressures or overloads arising out of available time.

The pace is not constant but a function of the activities to be executed. It is enforced by the speed of production by cooperative members. Since the pace is not constant, the person has the autonomy to decide his own cadence. In accordance with what the collaborators verbalize, the predominant rhythm for implementing activities is moderate.

The content of tasks is compatible in the operative mode, but there is evidence of differences between the work prescribed and the real work. The tasks undertaken by the members do not guarantee the production planning in a safe manner. However, a good progress of activities on site can be perceived. According to a survey, goals are met without any pressure from leaders, and the working environment is considered harmonious.

2.1 Identification of Sectors

The sectors are the specific work areas where workers execute activities developed in the cooperative. A general description of each sector follows.

The unloading area is the point of delivery for unloading materials collected by the municipal prefecture. This environment has become a ramp that serves as a support for the next production process stage in accordance with Figs. 1 and 2.

Fig. 1. Unloading area of materials.

Fig. 2. Unloading area of materials.

In Figs. 3, 4 and 5, several separation activities of materials involve inappropriate postures such as flexion of the trunk and neck. Furthermore, the limbs of the cooperators stay in static postures for long periods.

Fig. 3. Ramp and unloading area of materials.

Fig. 4. Materials separation table.

Fig. 5. Materials separation table.

There is a press in the pressing area to condition and prepare cardboard for sale (Fig. 6). In this case, note that flexion of the trunk of a cooperator is above 60° in order to collect materials left on the floor. Equally, the press operator works with flexion of the trunk, arms and forearms by applying force in areas outside the trunk.

Figure 7 shows paper separation activities at the front of the press. The cooperator drags weights manually without the aid of any cart or loading device. Additionally, they assume postures that are not recommended such as trunk rotation and flexion of the spine and neck.

Fig. 6. Workers in the pressing sector.

Fig. 7. Paper separation area.

After separation of electronic materials, they move along for disassembly and collection of materials with a financial value. The last step in the process is loading sacks on a truck in the courtyard where to make final sale of the materials (Fig. 8).

Fig. 8. Truck loaded for shipment of materials.

2.2 Description of Activities

Cooperative activities are implemented to achieve a specific, economic or organizational end. Each activity, in its own way, is encompassed by different stages. The activities described below were structured according to implementation monitoring in addition to delegated tasks assigned by managers of the cooperative.

- Loading material: This is manual labor activity performed at the time of delivery to unload recyclable materials transported from city hall. One of the main tasks is the total unloading of materials from the truck and directing it to the separators.
- Pre-sorting: Activity where a primary separation of material is performed manually, following the flow of the process after the unloading of material from the truck. The main task is to separate any packaging material according to its gross characteristics and allocate them into their respective sectors. Another important task is to screen all types of recyclable materials to classify and group them in accordance with their characteristics while using the tables for this purpose. The material is initially deposited in containers which are then transported to plastic bags after being filled.
- Sorting: A set of tasks where separation of recyclable materials is done according to their characteristics. Paper, which is one of the main products of the cooperative, is handled in the front of the ramp in the covered area of the shed. After pre-screening, it is separated by type.
- Press: This involves picking up all the cardboard type material and placing it in the press to produce bales for sale.
- Separation of electronic materials: Cooperators remove and separate any electronic materials using appropriate tools to dismantle industrial parts.
- Loading the truck: All the materials are transferred to the truck after being effectively separated to be sold.

- Manual transport: This involves carrying the containers full of materials and placing them in their respective plastic bags. Other transport activities include transferring the materials from the upper to lower area of the ramp and transporting the tailings of separated materials that have no economic value for the cooperative. In this case, these materials are transported out of the ramp and stored in plastic bags.

3 Conclusions

The relationship between a work organization and production factors directly influence the efficiency and productivity of a cooperative. This demand assessment is invaluable for encouraging more elaborate analyses and proposing future improvements. By establishing and obtaining data, it is possible to provide satisfactory results to maximize the economic gain by raising productivity indices.

This study also includes an expansion of the vision for tasks and activities. Furthermore, through the evaluation and understanding of work organization, it can provide improvements in the areas of health, safety and ergonomics. This is because working conditions, as well as their organization, directly affect the cooperative's financial results. The comfort of the worker and the physical environment are important because they reflect productivity gains.

Thus, the suitability of instruments, tools and equipment to minimize the effort and the optimization of time in the execution of work becomes a central necessity. Therefore, the conclusion for this cooperative was that the physical arrangement of the machinery and equipment can be studied and planned by mainly aiming at streamlining the flow of production and the roadmaps of products. Further studies can be carried out to improve the physical work environment, reduce noise, improve ventilation and lighting. In addition, a reflection on aspects related to work engineering, economic engineering and the study of physical arrangement could also be conducted to complement this study.

Regarding the postures adopted and the handling of loads, one should note the impact for execution of heavy tasks or not without due caution since there is frequent trunk and neck flexion, as well as the maintenance of a static posture of the lower limbs. In this sense, this study may contribute to the adoption of training and strategies for minimizing these work-related constraints.

References

1. Freitas, L.C.: Improvement of ergonomic working conditions in a recycling cooperative. In: II National Meeting of Researchers in Solidarity Economy, Annals of the II Enpes, São Paulo (2012)
2. Tupy, O., Yamaguchi, L.C.T.: Efficiency and Productivity: Concepts and Measurement. Agriculture in São Paulo, São Paulo - SP, vol. 45, no. 2, pp. 17–38 (1998)
3. Farrel, M.J.: A measurement of productive efficiency. J. R. Stat. Soc. **120**, 253–290 (1957)
4. Chiavenato, I.: General Theory of Administration. Makron Books, São Paulo (1993)

5. Oliveira, D.P.R.: Management Information System: Strategies, Operational Tactics, 2nd edn. Atlas, São Paulo (1993)
6. Silva, H.R.: Study of the ergonomics applied to the reuse and recycling of materials. In: Karwowski, W., Ahram, T. (eds.) Advances in Intelligent Systems and Computing, 1st edn., vol. 722, pp. 770–775. Springer, Cham (2018)
7. Silva, H.R.: Labor ergonomic analysis applied to a Brazilian solid materials recycling cooperative. In: Advances in Intelligent Systems and Computing, 1st edn., vol. 605, pp. 191–200. Springer, Cham (2018)

Workplace and Sexual Harassment: Time to Take a Second Look at the Law?

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Abstract. With the recent allegations regarding Harvey Weinstein and other famous figures in the entertainment industry taking over the news in recent months, there has been a renewed focus on sexual harassment (SH) worldwide. This paper takes a legal look at SH particularly in Ghana. In its submission, this paper discusses the controversies surrounding the meaning of SH and offers arguments characterizing it as an abuse of power at the workplace. The 21st Century dynamics of the menace are also examined and its prevalence presented in a global context. In conclusion, this paper offers relevant insights for improving Ghana's laws on SH.

Keywords: Sexual harassment · Workplace · Law · Ghana

1 Introduction

The 1992 constitution of Ghana even though with articles that speak to discrimination has no explicit mention of issues of sexual harassment. Article 12(2) of the 1992 constitution of Ghana reads "*Every person in Ghana, whatever his race, place of origin, political opinion, colour, religion, creed or gender shall be entitled to the fundamental human rights and freedoms of the individual contained in this Chapter but subject to respect for the rights and freedoms of others and for the public interest.*"[1] Before the inception of the Labour Act 2003, Act 651, Article 12(2) of the 1992 constitution were the only sections that a person could rely on in circumstances where he or she had experience any act of a sexual nature at work. The Criminal Code also has no provision on indecent assault such as sexual bodily contact with another person

[1] 1992 Constitution of Ghana, Chapter 5, Article 12(2).

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without the consent of the other person or sexual violation of the body of that person in any manner not amounting to carnal knowledge or unnatural carnal knowledge.[2]

The Labour Act 2003, Act 651 provides a fairly strong definition of sexual harassment which reads "a*ny unwelcome, offensive or importunate sexual advances or request made by an employer or superior officer or a co-worker, whether the worker is a man or woman*."[3] The prohibition is wide reaching, with 'unwanted conduct' broadly defined to include acts, requests, spoken words or gestures, and other forms of unwelcome conduct. It did not only end there with the definition but also classified a dismissal based on the sexual harassment as unlawful dismissal which comes with a remedy.[4] The common law principle of vicarious liability has been placed on a statutory footing under the Labour Act 2003, Act 651 such that sexual harassment claims can be brought not only against the alleged harasser but also the harasser's organization. However, this development has still not resulted in persons affected by this menace reporting their predicaments.

2 Sexual Harassment

2.1 Meaning and Controversies

Sexual harassment in the words of Robbins and Judge [1] is defined as "any unwanted activity of a sexual nature that affects an individual's employment and creates a hostile work environment" (p. 493). Though there remains some universal confusions with respect to what constitutes sexual harassment, great inspiration is drawn from the "litmus" test offered by the U. S. Supreme Court which ascertains whether some comments or behaviours at work will qualify to be reasonably perceived as abusive and hostile [2]. Generally, sexual harassment includes overt actions, like unwanted physical touching and coercive threats for sex to be exchanged for job offers and opportunities at work. These forms of harassment are relatively easy to spot and thus have over the years received commendable attention from organizations. However, there are other subtle actions, like unwanted comments and looks, sexual artifacts, some indelicate jokes or acts that can cross over the line of friendship into harassment [1]. These forms of sexual harassment seem to remain prevalent in today's work environment due to their covert and indirect nature but are all considered harmful once they are abusive or create hostility at work.

A controversial aspect of this menace is its residual nature in the harassed. In other words, the sole determiner of sexual harassment is the harassed. This leads to likely confusion of acts intended as friendly such as hugs to be, in some cases, regarded as harassment. Robbins and Judge [1] explain that women are more likely to regard certain acts and behaviours as harassment as compared to men. This is because men are in most cultures and traditionally considered as those who reserve the right to approach women for legitimate amorous relationships. This often results in women confusing

[2] Criminal Code 1960, Act 29, Section 103.

[3] Labour Act 2003, Act 651, Section 175.

[4] Labour Act 2003, Act 651, Section 63.

acts and expressions of men that demonstrate genuine love and care. What is even more worrying is the reservation of the judgement as to what constitute sexual harassment to mainly the harassed. This subjects advancements made in the conceptualization of sexual harassment to even greater debates in respect of whose perspective (the harassed or the harasser) should be taken in such cases [3].

2.2 Abuse of Power

Regardless of the controversies that surround what could be considered as sexual harassment, the factors underlying the act and its effect on the work environment basically translates it into an abuse of organizational power and formal authority [4]. Power is when an individual, A, influences another B in such a way that B does what A wants [5]. Power exists when there is a dependency relationship between two parties. This dependency is when an individual A possesses something that another individual B requires [6]. In this case, A will have power of B. The extent of dependency determines the extent of power an individual will possess. That is, the greater the dependency of an individual on another, the higher the power the latter will have on the former. The resources that an individual must possess to create dependency on himself or herself must be important, scarce and non-substitutable [7]. Importance means that the resource must be valuable and useful. Scarcity means that the resource must not be common and non-substitutability means that it must be difficult to replace the resource.

Sexual harassment basically falls into the power construct due to the abusive relationships among supervisors, co-workers and subordinates that come along with harassments. The formal power that supervisors often wield gives them coercive and reward powers [1]. The desire of employees for promotion, retention, increase in salary and favourable performance reviews thus create a dependency relationship characterized by unequal power in the supervisor – subordinate dyad [1]. This scenario often leads to situations where subordinates who are sexually harassed by their supervisors may have the challenge of either not voicing such acts out or even not knowing whom to report to due to fear of reprisal from the superior who has control over the same resources that the subordinate desires. Though rare, co-workers and even subordinates who have power over relevant information at the workplace, in some situations, could also abuse such powers by demanding for sexual favours.

No matter the perpetrator and the form in which it takes, sexual harassment typifies an abuse of power at the workplace and its consequences do not promote organizational success and high performance. Willnesa et al. [8] as cited in [1] summarily describe sexual harassment as “significantly and substantively associated with a host of harms” (p. 494).

Previous studies have shown that the occurrence of sexual harassment results in the harassed often engaging in negative work attitudes such as lower commitment, poor satisfaction and higher turnover intentions [1, 8, 9]. Sexual harassment also reduces group cohesion and productivity at the workplace. Norman et al. [10] also found that victims of sexual harassment suffered from physical injury, fear of the general public, psychological trauma and irritability at everyone, loss of trust for colleagues, disturbing memories, recurrent nightmares and emotional breakdown. Besides, women have been reported to suffer more in reported instances of sexual harassment due to the limited social power and vulnerable status [11]. These point to the fact that regardless of the factor that drives harassment at the workplace, it is an abuse to human dignity and defeats the creation of a healthy working climate and thus must not be tolerated under any circumstance.

2.3 A 21st Century Perspective

Sexual harassment in the 21st Century appears to have assumed some dynamics different from its traditional perspective of a male – female or a superior – subordinate "unwanted" relationship at work. More recently, the phenomenon has extended to hostile relationships between people of the same sex at work and involves people at all levels of the organization whether as a subordinate or supervisor.

Despite the legalization and public recognition of same sex marriages in several countries around the world, the phenomenon of sexual harassment is yet to receive adequate attention in law in most countries. This does not however dispute the fact that there are reported instances of same-sex sexual harassment on the rise in many countries [12]. But evidence in the United States seek to provide some legal suggestions for "evidentiary routes" for proving a same-sex sexual harassment violation.

In 1998, the case of same-sex sexual harassment was held by the United States Supreme Court as actionable under Title VII in the case of *Onacle v. Sundowner Offshore Services, Inc*[5]. In the said case, the Supreme Court Judges unanimously agreed that same sex harassment violated Title VII of the Federal Civil Rights Act of 1964. Ever since, there has been several cases of sexual harassment between people of the same sexes held in courts in the United States and other parts of the world (see[6,7,8]). A study by Dubois, Knapp, Faley and Kustis [13] involving respondents comprising males and females found that male targets of same-gender sexual harassment experienced consequences that were more pervasive and severe than those experienced by male targets of sexual harassments involving opposite genders. Again, Fineran [14] describes same-sex sexual harassment as sexual violence that has considerable mental health implications for both males and females.

Considering the rise of this form of sexual harassment in the 21st Century, there is the need for sufficient legislative provision about same-sex marriage; a necessity that is apparently missing in Ghana's laws. The Supreme Court of the United States however provide some "evidentiary routes" that could be used to prove a sexual harassment violations. First, the offer that the harasser is a homosexual and thus primarily motivated by sexual desire. Second, a victim needs to be harassed in such sex-specific and derogatory terms by someone who has the same gender as to make it clear that the harasser is motivated by general hostility to the presence of someone of the same gender in the

[5] Oncale v. Sundowner Offshore Servs., Inc., 523 U.S. 75, 118 S. Ct. 998, 140 L. Ed. 2d 201 (1998).

[6] Rosas v. Balter Sales Co.

[7] EEOC v. Michael Cetta Inc. d/b/a Sparks Steak House.

[8] EEOC v. Pitre, Inc.

workplace. Finally, the Supreme Court provides that there is a direct comparative evidence about how the alleged harasser treated members of both sexes in a mixed-sex workplace. These provisions offer significant basis for addressing issues of same-sexual harassment, a phenomenon that is trending in the 21st Century.

Also, reports of sexual harassment in the 21st Century has witnessed the unspoken issues of supervisors being harassed sexually by their subordinates. These acts are less rampant between female supervisors and male subordinates but are not impossible. In the case of the cigarette manufacturer, Philip Morris, female supervisors were subjected to series of sexual abuses by their male subordinates [1]. In such cases, the women are devalued through gender stereotypes that produce negative energy among the female supervisors. In some cases, male supervisors are also sexually harassed by their female subordinates but such cases are quite controversial since men are often considered as relatively highly oriented towards sex than women.

These trends of sexual harassment offer new challenges to legal provisions like that existing in Ghana which are yet to factor in the recent dynamics of sexual harassment. Nevertheless, it must be emphasized that the phenomenon of sexual harassment is not only peculiar to the Ghanaian context but has a very wide reaching impact across the globe.

3 Sexual Harassment: A Global Menace

Sexual harassment could be described as a global menace due to its pervasiveness across countries and various economic sectors. A joint Reuters/Ipsos global poll of 12,000 workers in 24 countries revealed a damaging report of the menace of sexual harassment. The report revealed that 26% of workers in India, 18% of workers in China, 16% of workers in Saudi Arabia, 13% of workers in Mexico and 10% of workers in South Africa were most likely to report having experienced one form or the other of sexual harassment. The report revealed also 9% of workers reported sexual harassment in Italy and a total of 8% reported same in Brazil, Russia, South Korea and the United States of America. In Europe, 5% of workers in Poland, Germany and Belgium reported sexual harassment with 6% reporting it in Spain. 4% of workers reported sexual harassment in Britain and in Australia while 6% also reported same in Spain, Canada, Japan and Argentina. Also, 7% of workers reported sexual harassment in Hungary. Summarily, the report found that one out of 10 workers globally reported having experienced sexual harassment at work.

The joint Reuter/Ipsos survey also revealed that workers who were aged below 35 years were most likely to report experiencing sexual harassment at their workplace. This gives an indication of the persistence of the problem of sexual harassment and no proper end of sight of the menace especially when early career workers and organizational entrants are those most vulnerable to the spate of sexual harassment.

A critical examination at the trend reveals not only the pervasiveness of the menace, but also a subtle relationship between sexual harassment and the development level of the country. Reports on sexual harassment in developing countries such as India and

Saudi Arabia as compared to developed economies such as Britain and Germany reveal that the less developed a country is, the more likely there are going to be reports of sexual harassment. Developing countries are characterized as sovereign states with a less developed industrial base and a low Human Development Index [15]. The development of the industrial base involves the enactment of legislations that promote a safe and healthy working environment. This provides some background to the fact that workers in developing or less developed countries are more likely to report sexual harassment. This however does not exempt the developed countries from incidence of sexual harassment. A recent survey by the BBC Radio 5 live of British adults showed that about half of British women and about a fifth of men have been sexually harassed at their work or school[9].

This confirms the prevalence of sexual harassment across boundaries. Nonetheless, what remains is the protection and promotion of the rights of workers through the law. Though the Ghanaian law has made some progress recognizing sexual harassment as a violation of the right of workers, several loopholes still remain and this study identifies these problems and offers suggestions for legal reforms.

4 Problems with the Current Ghanaian Law

The current state of the law has fallen short in defining what will constitute work space. There are no clear indications given either by precedents or by statute which in this case is the Labour Act, 2003, Act 651. For example, in the Employment Equality Act 1998-2005, the prohibition covers sexual harassment not just at work, but also on training courses, work trips, and other work-related activities including social events. Employers can be held liable for sexual harassment perpetrated by employees and non-employees (clients, customers and other business contacts) where the employer has some control over the perpetrator. It appears provisions in the Ghanaian law are loose in this regard and need provisions to carter for it.[10]

Furthermore, there seem not to be a strong relationship between the Labour Commission and various employers with respect to drafting policies that could be adhered to by all which is drafted with the input of various stakeholders. For example Ireland has a code prepared by the Equality Authority with the approval of the Minister for Justice and Equality and after consultation with various labour unions and other relevant organisations representing equality interests which aims at giving practical guidance to employers, employers' organisations, trade unions and employees on what is meant by sexual harassment and harassment in the workplace, how it may be prevented and what steps to take if it does occur to ensure that adequate procedures are readily available to deal with the problem and to prevent its recurrence.[11] It is imperative to add that, the

[9] The ComRes Poll for BBC Radio 5 live involved over 2,000 respondents. The survey was necessitated after sexual assault claims were levelled against Harvey Weinstein leading to several other sexual harassment stories.

[10] The Employment Equality Act 1998-2005.

[11] S.I. No. 208/2012 - Employment Equality Act 1998 (Code of Practice) (Harassment) Order 2012.

provisions of this code are admissible in evidence and if relevant may be taken into account in any criminal or other proceedings before a court and under Part VII of the Employment Equality Act (see Footnote 10), and also in proceedings before the Labour Court, the Labour Relations Commission, the Employment Appeals Tribunal, the Equality Tribunal and a rights commissioner. I believe having such a document will not only put employers or employees on their toes but will also provide the courage for victims to report such acts.

Finally, though Ghana's laws seem to make direct reference to the gender of the harasser – a legal provision that is emphatic and indicative of Ghana's position with respect to the same-sex sexual harassment – the law seems to have left out an important aspect of an upward direction of sexual harassment. In other words, the law ignores subordinates harassing superiors. With a specific statement of the harasser being an employer, superior officer or a co-worker, the law presumptively dismisses the likelihood of low level workers harassing their supervisors. Drawing from the Philip Morris case stated earlier in this study, there seems to be a lot of relevant legislative lessons for Ghana. Ghana is a highly masculine culture where the roles of women and men are divided among them based on gender. Men in masculine cultures are regarded as those who should be assertive and natural leaders while women are considered as soft, calm, considerate and caring [16]. Women in cultures like Ghana are thus least considered as intrinsically having the macho traits that is required of leaders. Hence, the Philip Morris kind of sexual harassment where women are sexually abused through their devaluation as being helpless is more likely to occur in the Ghanaian workplace. It is thus for important for the Ghanaian law, particularly the Labour Act, Act, 2003, Act 651 to summarily spell out all the directions from which workers could experience sexual harassment. In other words, the law should be extensive to include all kinds of harassers at the workplace regardless of their position.

5 Conclusion

There are adverse costs arising from sexual harassment and harassment for employers. It has a direct impact on the profitability of the enterprise where staff take sick leave or resign their posts because of sexual harassment or harassment. It can also have an impact on the economic efficiency of the enterprise where employees' efficiency is reduced by having to work in a climate in which the individual's honour is not respected. There is therefore the need to take a critical look at the state of the current law and amend it to meet up with the exigencies surrounding the phenomenon.

References

1. Robbins, S.P., Judge, T.A.: Organizational Behaviour, 13th edn. Pearson Education, Harlow (2009)
2. Silverstein, S., Christian, S.: Harassment Ruling Raises Free Speech Issues. Los Angeles Times, D2, 11 November 1993
3. Rotundo, M., Nguyen, D., Sackett, P.R.: A meta-analytic review of gender differences in perceptions of sexual harassment. J. App. Psych. **86**, 914–922 (2001)
4. Malamut, A.B., Offermann, L.R.: Coping with sexual harassment: personal, environmental, and cognitive determinants. J. Appl. Psych. **86**, 1162–1166 (2001)
5. Bass, B.M.: Bass & Stogdill's Handbook of Leadership, 3rd edn. The Free Press, New York (1990)
6. Emerson, R.E.: Power-dependence relations. Am. Soc. Rev. **27**, 31–41 (1962)
7. Mintzberg, H.: Power in and Around Organizations. Prentice Hall, Upper Saddle River (1983)
8. Willnesa, C.R., Steel, P., Lee, K.: A meta-analysis of the antecedents and consequences of workplace sexual harassment. Pers. Psych. **60**, 127–162 (2007)
9. Whatley, M.A., Wasieleski, D.T.: The Incidence of Sexual Harassment in Academia: A Pilot Study. Department of Psychology, Valdosta State University (2001)
10. Norman, I.D., Aikins, M., Binka, F.N.: Sexual harassment in public medical schools in Ghana. Ghana Med. J. **47**(3), 128–136 (2013)
11. Magley, V.J., Waldo, C.R., Drasgow, F.: The impact of sexual harassment on military personnel: is it the same for men and women? Mil. Psych. **11**, 283–302 (1999)
12. MJPOSPIS: Same-sex Sexual Harassment (2017). https://pospislaw.com/2017/01/15/same-sex-sexual-harassment/. Accessed 20 Feb 2018
13. Dubois, C.L.Z., Knapp, D.E., Faley, R.H., Kustis, G.A.: An empirical examination of same- and other-gender sexual harassment in the workplace. Sex Roles **39**(9/10), 731–749 (1998)
14. Fineran, S.: Sexual harassment between same-sex peers: intersection of mental health, homophobia, and sexual violence in schools. Soc. Work **47**(1), 65–74 (2002)
15. O'Sullivan, A., Sheffrin, S.M.: Economics: Principles in Action. Pearson Prentice Hall, Upper Saddle River (2003)
16. Darety-Baah, K.: The cultural approach to the management of the international human resource: an analysis of Hofstede's cultural dimensions. Int. J. Bus. Admin. **4**(2), 39–45 (2013)

Social and Occupational Factors of Comfort, Discomfort and Pain

Fuzzy Model Evaluation of Vehicles Ergonomics and Its Influence on Occupational Diseases

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Abstract. The problems of synthesis of hybrid fuzzy decision rules of ergonomic level evaluation of vehicles and its influence to the drivers' health condition has been reviewed in current article Our investigations show that the confidence in correctness of decision making in prediction of such diseases as osteochondrosis of the lumbar spine and prostitutes located in the level 0.8, and the early diagnosis of these diseases is carried out with confidence 0.9.

Keywords: Fuzzy hybrid mode confidence in the decisions
The level of ergonomics occupational diseases

1 Introduction

The impact of the role of technical means, including transport, on the state of human health has been studied for many years in all countries of the world. The fact of such influence is established, but the obtained dependences are rarely made out in the form of mathematical models providing the acceptable quality for forecasting, early and differential diagnosis of occupational diseases of drivers of vehicles. Proceeding from this, the goal of this work is the development of methods for quantitative assessment of the level of ergonomics of vehicles and the synthesis of mathematical models for forecasting and early diagnosis of diseases provoked by the professional activity of drivers. The indicators of ergonomics, characterizing the convenience and comfort of a person in contact with technical systems, consist of a series of hygienic, anthropometric, physiological (psychophysical) and psychological characteristics. In turn, each of these characteristics (subgroups) is described by a set of disparate indicators. For

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example, a subgroup of hygienic indices is characterized by a microclimate (temperature, humidity, pressure), noise level, vibration and overloads, illumination, level of emissions, level of mobility and change of air flow, air mixture composition, magnetic strength level, electric and electromagnetic fields, the level of toxicity and the level of dustiness. From the mathematical point of view, the initial indices used to assess ergonomics are most often measured on fairly well-interpreted scales. At the same time, the complex characteristics of ergonomics, the more the level of ergonomics of the product as a whole does not have a clear formal interpretation [1–10]. In the presence of clearly defined initial measurement scales and indistinctly related notions of the level of ergonomics, it is advisable to use the theory of fuzzy logic of decision-making and the theory of measuring latent variables with G. Rush's model as the basic mathematical device for constructing a model for quantitative estimation of ergonomic levels [11]. In relation to mathematical models of prediction and early diagnosis of occupational diseases, the level of ergonomics is one of the quantitative information features, and the classes corresponding to the investigated diseases have fuzzy boundaries with large areas of intersections poorly defined by experts, since there are no clear boundaries between health and pre-illness, between pre-illness and illness. In such circumstances, the use of fuzzy logic of decision-making and its modifications developed at the Department of Biomedical Engineering in Southwest State University in Russian Federation [12–15]. Bio-active points of the system operators based on fuzzy logic measurements show a connection between ergonomics and emotional tension. The emotional tension on humans is developed by means of psychological tests connected with the psycho-emotional sphere and on indicators characterizing the state of a subject's visual attention [16, 17]. Each of these two areas determines several factors for psycho-emotional tension. The level of tension is determined as an aggregate of these two components with the rules of fuzzy logic. The membership functions and solving rules for the psychological tests, and for the state of visual attention, are constructed using fuzzy logic theory. It is shown that the resulting method can be used as an informative feature for prediction of many properties, such as the situational awareness (training and experience) of an operator and the operator's individual capacity to function (mental–physiological limits). The second group of indicators characterize properties such as switchable attention (the ability to switch attention) (SWA), concentration (ability to concentrate) (CNA), stability of visual attention (STA) and parameters determining the state of memory. One of the most important issues for man–machine systems is to evaluate the performance of operators under abnormal conditions such as stress or tension. Also, when we use [28], the Methods for the selection of candidates for operators of man–machine systems are analyzed based on ergonomic system. Vector mean estimates of group intelligence and estimates defining the group's collective decision-making ability to obtain the unified solution to the selection problem and to retain the correct original solution to the problem, and estimates of solution quality and interoperability in correct decision-making are proposed. The properties of the suggested estimates are studied with a test example of five candidates. Amongst these properties are estimates of the group's psychological traits, such as average estimates of professional competence, static components of the intelligence vector for tested candidates, components of the trainability vector for tested candidates, average intelligence estimates for tested candidates, average estimates for the basis of groups, average different-mindedness estimates of groups, variations in the trainability of operators, and arithmetic estimates of group intelligence variability such as levels of awareness, knowledge level, mean speed of knowledge variation, comprehension and motivation in operators' reasoning [18, 19]. All the above results are related with the level of ergonomics. In other words, as the level of ergonomics increases the results will improved. Several examples of artifacts in real EEG signals depend on the functions of ergonomics level U_s (x_i). According to [20, 21] mathematical models were applied for the interaction of the internal and biological active points of meridian structures. It is shown that the use of fuzzy logic decision-making yields good results for the prediction and early diagnosis of diseases depending on the reaction energy of biological active points (acupuncture points). It is worthy of noting that the above results are related to the level of ergonomics. In the [22] the paper discusses the problems of determining the ergonomics level of technical systems based on fuzzy mathematical models. The role of the ergonomics in development and occurrence of occupational diseases using sets of hybrid fuzzy decision was studied. Checking decision rules on representative test samples showed that the resulting system of fuzzy inference rules can solve the problem of predicting the appearance of cochlear jade with confidence above 0.87 early diagnosis of the disease which allows recommending the use of the results obtained in clinical practice.

2 Models and Methods

As in the classical fuzzy logic of decision-making, the main element of the developed models is the function of belonging to the fuzzy concept A $\mu_A(x_i)$ with the basic variable characterizing this concept x_i. In the context under consideration, we introduce the notion of a function of belonging to a level of ergonomics with a basic variable defined by elementary (simple) indices x_i [23, 24].

In order to emphasize the difference between this type of membership functions of their other types used in this work function relating to ergonomics private call feature ergonomic level $f_{UE}(x_i)$ with scope [0,…,1]. To determine the level of ergonomics for a selected characteristic UE_x it is necessary to aggregate the corresponding particular functions of the ergonomic level:

$$UE_x = F_x[f_{UE}(x_i)] \tag{1}$$

when F_x - aggregator of frequency functions $i = 1, \ldots n_x$;

n_x - the number of indicators in the characteristic of the level of ergonomics

To quantify the level of ergonomics of the product as a whole, the aggregation of the selected characteristics

$$UE_0 = F_0(UE_x), \tag{2}$$

when F_0 - aggregator at the level of characteristics.

The choice of the type of aggregators is carried out depending on the types and properties, the indicators used and the chosen research objectives (assessing the level of ergonomics on a continuous scale, the classification of the level of ergonomics on a continuous scale, the classification of the level of ergonomics on a qualitative scale, the use of ergonomic indicators to predict changes in the functional state or state the health of the human operator in contact with the technical means, the evaluation of the reliability of the work of human-machine systems and etc.).

Most often as aggregators, fuzzy unification and (or) intersection operations are chosen:

$$\begin{aligned} &UE = \min_i [f_{UE}(x_i)];\ UE = \min_j \left[f_{UE}\left(Y_j\right)\right];\ UE = \min_{i,j} \left[f_{UE}(x_i), f_{UE}\left(Y_j\right)\right]; \\ &UE = \max_i [f_{UE}(x_i)];\ UE = \max_j \left[f_{UE}\left(Y_j\right)\right];\ UE = \max_{i,j} \left[f_{UE}(x_i), f_{UE}\left(Y_j\right)\right]; \\ &UE = \max_q\ \min_i \left[f_{UE_q}(x_i)\right];\ UE = \max_q\ \min_j \left[f_{UE_q}\left(Y_j\right)\right]; \\ &UE = \max_q\ \min_{i,j} \left[f_{UE_q}(x_i), f_{UE_q}\left(Y_j\right)\right], \end{aligned} \tag{3}$$

when $Y_j = f_j(x_1, \ldots, x_n)$ - a complex indicator characterizing the ergonomics of products determined by the functional dependence on simple (primary) indicators obtained by the methods of clear mathematics (discriminant analysis, regression analysis, empirical formulas, etc.); q - number of the approximating fuzzy hyper parallel in the feature space x_i.

Widely used were also aggregators, which are a modification of the iterative formula of E. Shortlif

$$\begin{aligned} UE(p+1) &= UE(p) + f_{UE}(x_i)[1 - UE(p)] \\ UE(p+1) &= UE(p) + f_{UE}\left(Y_j\right)[1 - UE(p)] \\ UE(p+1) &= UE(p) + US(p+1) \cdot [1 - UE(p)] \end{aligned} \tag{4}$$

when p - iteration number in calculation UE; $US(p+1)$ - a particular level of ergonomics in the subspace with the number $p+1$ of multidimensional feature space x_i.

The tasks of forecasting occupational diseases will be defined as two-class classification problems: class ω_0 - for a predetermined time T_z the subject will not fall ill with the disease chosen for the analysis; ω_ℓ - for a time T_z the subject, with a high probability, will become a class of diseases ω_ℓ.

For this class of tasks in accordance with the recommendations [25, 26] introduced the concept of functions $\mu_{\omega_\ell}(x_i)$, $\mu_{\omega_\ell}\left(Y_j\right)$ belonging to classes of high risk of diseases ω_ℓ, when x_i and Y_j - basic variables, identified as risk factors for disease ω_ℓ.

For the problem of early and differential diagnosis, ω_ℓ are defined as classical recognition problems with the introduction of membership functions $\mu_{\omega_\ell}(x_i)$, $\mu_{\omega_\ell}\left(Y_j\right)$ with basic variables from the list of informative features x_i, Y_j [27, 28]. The methodology of synthesis of hybrid fuzzy decision rules for forecasting and medical diagnostics is described in detail in the works [29, 30]. This methodology, depending on the data structure of the researched at the stage of exploration, is based on the combination of different types of basic models based on the fuzzy decision logic of L. Zadeh UGN_ℓ; separating surfaces UGG_ℓ; Short if's theory of confidence UGS_ℓ; on fuzzy interactive classifiers UGD_ℓ; on the fuzzy modification of the method of group accounting of arguments UGM_ℓ; on the models of G. Rush UGR_ℓ and fuzzy modification of A. Wald UGV_ℓ. Recommendations for the synthesis of these models can be found in the works [31, 32].

In the general form, when synthesizing groups of hybrid decision rules, known mathematical methods can be used, for example, pattern recognition theories, using indicators UGN_ℓ, UGG_ℓ, UGS_ℓ, UGD_ℓ, UGM_ℓ, UGR_ℓ and UGV_ℓ as generalized space of informative features. With the use of soft computing technology, such synthesis is expedient to be performed taking into account the specific features of the tasks being solved. For example, different in nature groups of attributes are aggregated by their "own" types of decision rules. In another variant, each of the rules entering into the collective processes all the informative features. A mixed version is possible, in which different decision rules use mixed possibly overlapping, groups of informative attributes. Such groupings can be created on a different basis: at the cost of obtaining information; by measurement time; informative; on the structure of data, etc. [33, 34]. Variants of final aggregation of decision rules can also be different. The aggregation methods for various types of data are described in [35–37].

3 Synthesis Results

Practical results have been obtained for vehicles that are widely used at Russian Emergency Situations Ministry enterprises. As elementary indicators characterizing the ergonomics of the workplace of drivers of vehicles at the expert level were selected: a method of regulating the temperature in the cabin (x_1); average temperature in the cabin (x_2); average level of load on hands (x_3); average level of load on the legs (x_4); seat angle (x_5); seat height (x_6); subjective sensations in the lumbar part from sitting during the shift period (x_7); subjective sensations in the sciatic part of the seat during the shift period (x_8); distance to the main controls (x_9); subjective feelings from interaction with the dashboard (x_{10}); level of psycho emotional stress associated with professional activities (x_{11}) and level of chronic physical fatigue (x_{12}) [38–43].

Two approaches have been chosen for constructing particular functions of the ergonomics level in terms of the characteristics $x_1,\ldots,$ x_{10}: the method of psychophysical scaling and the construction of specialized test questionnaires.

For the signs x_7–x_{10}, experts compiled test questionnaires optimized using the G. Rush model [44].

The signs $x_1,\ldots,$ x_{10} are measured using the appropriate technical means.

Levels of psycho emotional stress and fatigue are used as basic variables for ergonomic functions $f_{UE}(x_{11}), f_{UE}(x_{12})$. These levels are determined using the combined mathematical models described in [45–48].

Functions of the ergonomic level as a variety of classification membership functions are built by experts working on Delphi technology in accordance with the recommendations given in [49]. The choice of the type of aggregating function is carried out in the course of exploration analysis in accordance with the recommendations of the authors [36, 50–54].

As a result, the most appropriate model was chosen as follows:

$$UE = \min[f_{UE}(x_1), f_{UE}(x_2), \ldots, f_{UE}(x_{12})] \tag{5}$$

Using the UE scale as a base variable, the experts identified four classes of vehicle ergonomics level: unsatisfactory, satisfactory, good and excellent level.

Figure 1 shows the corresponding graphs of the classification functions belonging to $\mu_g(UE)$.

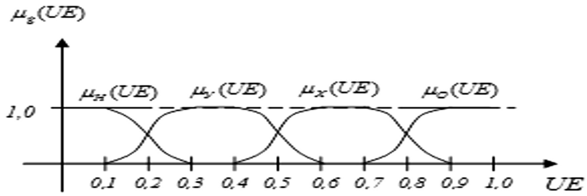

Fig. 1. Graph functions belonging to the class level of ergonomics of the vehicle cabin

In Fig. 1 the following designations of membership functions are accepted: unsatisfactory $\mu_{\mathcal{H}}(UE)$, satisfactory $\mu_y(UE)$, good $\mu_x(UE)$, and excellent $\mu_o(UE)$ ergonomic. The decision on the level of ergonomics of the tractor cab is made according to the maximum value $\mu_s(UE)$ (s = H, y, x, o).

Analysis of occupational diseases among drivers of vehicles showed that among drivers for a long time behind the wheel without a sharp temperature profile and with satisfactory conditioning of the cabin, the most common diseases are osteochondrosis and prostitutes. Drivers, who work in conditions of poor air conditioning in the cabin and often leave the cabin with access to the external environment with a sharp temperature difference, acquire respiratory system diseases. Some drivers work in environmentally unfavorable conditions (presence of carbon monoxide, phenols, etc.), which can lead to diseases provoked by harmful environmental substances.

In this paper, we will consider the synthesis of mathematical models for predicting and early diagnosis of diseases such as osteochondrosis and prostitutes.

At the expert level for the disease of osteochondrosis, ergonomic and individual risk factors were introduced. For classes of high risk of osteochondrosis and its early stage, the following risk factors are selected [1]: x_1 - weight redundancy, x_2 - heredity, x_3 - defects of posture (scoliosis, stoop, etc.), x_4 - accompanying illnesses, x_5 - excessive static load on the lumbosacral spine, x_6 - excessive dynamic load on the lumbosacral spine, x_7 - adverse microclimate, x_8 - work in vibration, x_9 - the habit of sitting hunched.

The next group of symptoms is associated with painful sensations, which are characteristic of preillness and disease. This group of signs included the following factors (pain factors): x_{10} - pain in the lumbosacral spine, arising for no apparent reason; x_{11} - pain in the lumbosacral spine, arising after hypothermia; x_{12} - pain in the lumbosacral spine arising after physical exertion; x_{13} - maximum duration of pain in the lumbosacral spine; x_{14} - the prescription of pain in years; x_{15} - increased pain in the lumbosacral spine for the last year.

According to the given system of signs without taking into account pain factors, which, according to experts, characterize classes of pre-illnesses and illness, functions of belonging to a class of high risk of osteochondrosis ω_{PO} in the next three years.

Using the aggregating function of type (2) for all risk factors, the confidence in the correct prognosis is greater than 0.75, and with the addition of risk factors such as prolonged psycho emotional overstrain and chronic physical fatigue, the confidence in the correct prognosis is greater than 0.85.

To determine the stage of pre-sickness (class ω_{PO}), the functions of adjunctness in x_{10}–x_{15} were obtained.

The general confidence in the class is determined by the formula (2) and reaches a value of 0.9; which is enough for practical use.

A distinctive feature of osteochondrosis is that with the same pain syndromes and common risk factors, the final diagnoses may differ significantly.

For example, with lumbosacral pain of an unknown origin, tumor processes, chronic arterial insufficiency of the lower extremities, can cause them etc., which requires additional special studies [55, 56].

To solve the problem of predicting the onset and exacerbation of chronic prostitutes (class ω_{PX}, ω_{OX}) specialists urologists identified 55 informative signs broken down into five large blocks [57] I - socioeconomic factors $x_1,\ldots, x_4$; II - ergonomic factors $x_5,\ldots, x_{13}$; III - behavioral factors $x_{14},\ldots, x_{34}$; IV - nutritional factors $x_{35},\ldots, x_{40}$; V - biomedical factors $x_{41},\ldots, x_{55}$. A complete list of all risk factors with the decoding of their gradations is given in [42].

For the diagnosis of chronic prostitutes, urologists have developed a system of diagnostic features, obtained based on an investigation algorithm developed with the recommendations of the International Conciliation Conference on improving the diagnosis and treatment of prostitutes and the algorithm for examining patients with chronic prostitutes. The working vocabulary of signs includes: sub-objective signs obtained by questioning patients on a questionnaire developed on the basis of questionnaires NIH-CPSI, IIEF-5, TES-CP (Russian questionnaire): x_1 - localization of pain or discomfort; x_2 - the appearance or intensification of pain after sexual intercourse; x_3 - pain or discomfort at the end of sexual intercourse (ejaculation); x_4 - pain or burning when urinating; x_5 - weakening of the urine stream, intermittent urination or feeling of incomplete emptying of the bladder; x_6 - the urine needs to urinate earlier than 2 h after the last urination; x_7 - frequency of nocturnal urination; x_8 - prolonged discharge of urine by drops after urination; x_9 - secretion of the secretion of the prostate at the end of urination or during defecation; x_{10} - the total score of the scale of erectile function (ICEF); x_{11} - frequent causeless erections; x_{12} - premature ejaculation; x_{13} - decreased quality of orgasm; x_{14} - infertility; objective signs: the results of digital rectal examination: x_{15} consistency + gland dimensions: x_{16} - the structure of the gland; x_{17} - symmetry; x_{18} - soreness; diagnostic prostate massage: x_{19} - the amount of secretion of the prostate in the drops: x_{20} - post-compression deformation; microscopic examination of the secretion of the prostate: x_{21} - the number of white blood cells with microscopy of the smear; x_{22} - the amount of lecithin grains; x_{23} - detection of micro flora during smear microscopy; x_{24} - microbiological examination of prostate excrement; x_{25} - Prostate transrectal ultrasound data; x_{26} - PCR results of prostate secretion.

A detailed description of the structure of this feature space is given in [58].

After optimizing the structure of the characteristic space, the information produced with the use of the package RVMM2020 left 20 informative signs ensuring confidence in the correct diagnosis of at least 0.9.

4 Conclusion

1. The method of synthesis of hybrid fuzzy models for describing and estimating the level of ergonomy of vehicles, based on the aggregation of heterogeneous indicators characterizing their ergonomics makes it possible to assess the level of ergonomics of individual elements and units and vehicles in general and take into account their influence on health drivers.
2. The synthesized system of fuzzy inference rules allows solving problems of forecasting the appearance and exacerbation of osteochondrosis of the lumbar spine and prostitutes with confidence - no worse than 0.8 and establish the presence of early stages of these diseases with confidence - no worse than 0.9, which allows us to recommend mathematical models for use in medical practice.

References

1. Efremov, M.A., Korenevsky, N.A., Rodionov, O.V., Filist, S.A.: Forecasting of the onset, early and differential diagnosis of osteochondrosis of the lumbar spine based on fuzzy logic of decision-making. Syst. Anal. Manage. Biomed. Syst. **5**(4), 939–942 (2006)
2. Kopteva, N.A., Korenevsky, N.A.: Forecasting and diagnosis of occupational diseases in workers of the agro-industrial complex, no. 2, pp. 14–16. West-nickname of the Kursk State Agricultural Academy (2008)
3. Korenevsky, N.A.: Use of fuzzy decision logic for medical expert systems. Med. Technol. **1**, 33–35 (2015)
4. Korenevsky, N.A.: The method of synthesis of heterogeneous fuzzy rules for analysis and control of the state of biotechnical systems. In: News of the South-Western State University. Series: Management, Computer Science, Computer Science. Medical Instrument Making, vol. 2, pp. 99–103 (2013)
5. Korenevsky, N.A., Rutskoi, R.V., Dolzhenkov, S.D.: The method of forecasting and diagnosing the state of health on the basis of teams of fuzzy decisive rules. Syst. Anal. Manage. Biomed. Syst. **12**(4), 905–909 (2013)
6. Korenevsky, N.A., Razumova, K.V.: Synthesis of teams of hybrid fuzzy models, estimating the state of complex systems. High Technol. **15**(12), 31–40 (2014)
7. Korenevsky, N.A., Krupchatnikov, R.A., Al-Kasasbeh, R.T.: Theoretical bases of biophysics of acupuncture with applications in medicine, psychology and ecology based on fuzzy network models, 528 p. TNT, Stary Oskol (2013)
8. Korenevsky, N.A., Korostelev, A.N., Serebrovsky, V.V., Sapitonov, T.N.: Fuzzy assessment of the ergonomics of agricultural machines and its use in assessing the condition of workers in the agro-industrial complex. Bull. Kursk State Agricult. Acad. **1**, 122–126 (2012)

9. Korenevsky, N.A., Serebrovsky, V.I., Govorukhina, T.N., Kopteva, N.A.: Forecasting and Diagnostics of Diseases Caused By Harmful Industrial and Environmental Factors on the Basis of Heterogeneous Non-Clear Models, 231p. Publishing house Kursk, Kursk (2012)
10. Korenevsky, N.A., Burmaka, A.A., Starodubtseva, L.V., Gorbatenko, S.A.: Estimation of ergonomics of vehicles based on odd hybrid models. Biotechnosphere **1**(14), 50–54 (2012)
11. Korenevsky, N.A., Shortlifa, E., Korenevsky, O.N., Gadalov, V.N., Korovin, E.N., Serebrovsky, V.I.: Evaluation of ergonomics of biotechnical systems using fuzzy models. Med. Technol. **4**, 4–6 (2013)
12. Korenevsky, N.A., Ryabkova, E.B.: Method for synthesizing fuzzy decision rules from information on the geometric structure of multidimensional data. Bull. Voronezh State Tech. Univ. **7**(8), 128–137 (2011)
13. Korostelev, A.N., Korenevskii, N.A., Korostelev, A.H.: Use of heterogeneous fuzzy models for complex estimation of the level of human functional reserve. Bull. Voronezh State Tech. Univ. **7**(8), 142–147 (2011)
14. Kotsar, A.G.: Development and research of methods and means for managing the prognosis, diagnosis, prophylaxis and treatment of chronic prostatitis, 147 p. PhD in 2008 Voronezh (2003)
15. Serebrovsky, V.I., Boytsov, A.V., Shutkin, A.N., Korenevskaya, S.N.: Synthesis of the decisive rules for assessing the level of psychoemotional tension and fatigue using two-dimensional classification spaces and vector algebra. News of the South-Western State University, vol. 5, no. 56, pp. 58–63 (2014)
16. Titov, V.S., Mishustin, V.N., Novikov, A.V., Korovin, E.N.: Classification of functional states and assessment of the level of psycho-emotional stress and fatigue based on hybrid fuzzy models. Med. Technol. **4**, 11–14 (2013)
17. Chursin, G.V., Korenevsky, G.V., Burmaka, A.A., et al.: Predicting, early and differential national drivers of vehicle diseases using fuzzy models. Biomed. Radioelectron. **2**, 54–63 (2010)
18. Chursin, G.V., Korenevsky, N.A., Korostelev, A.N., et al.: Complex estimation of ergonomic properties of vehicles based on fuzzy models and its use in problems of prediction and diagnosis of occupational diseases. Syst. Anal. Manage. Biomed. Syst. **9**(1), 21–26 (2010)
19. Chursin, G.V., Korenevsky, N.A., Lukashov, M.I.: Fuzzy assessment of the role of physical fatigue in the recurrence of chronic diseases. In: System Analysis and Management in Biomedical Systems, vol. 8, no. 3, pp. 692–697 (2009)
20. Korenevskiy, N.A., Al-Kasasbeh, R.T., Ionescou, F., Alshamasin, M., Alkasasbeh, E., Smith, A.P.: Fuzzy determination of the human’s level of psycho-emotional. In: IFMBE Proceedings, vol. 40, pp. 213–216 (2013)
21. Korenevskiy, N.A., Al-Kasasbeh R.T., Ionescou, F., Alshamasin, M., Al-Kasasbeh, E., Smith A.P.: Fuzzy determination of the human’s level of psycho-emotional. In: Mega-Conference on Biomedical Engineering: Proceedings of the 4th International Conference of the Development of Biomedical Engineering, Ho Chi Minh City, Vietnam, 8–12 January 2012, pp. 354–357 (2012)
22. Korenevskiy, N.A., Gorbatenko, S.A., Krupchatnikov, R.A., Lukashov, M.I.: Design of network-based fuzzy knowledge bases for medical decision-making support systems. Biomed. Eng. **43**(4), 187–190 (2009)
23. Al-Kasasbeh, R.T., Zaubi, M.A.A., Korenevskiy, N., Al-Shawawreh, F., Alshamasin, M.S., Ionescu, F.: A biotech measurement software system using controlled features for determining the level of psycho-emotional tension on man-machine system operators by bio-active points based on fuzzy logic measures. Int. J. Model. Identif. Control **22**(4), 375–395 (2014)

24. Al-Kasasbeh, R.T.: Biotechnical measurement and software system controlled features for determining the level of psycho-emotional tension on man–machine systems by fuzzy measures. Adv. Eng. Softw. **45**, 137–143 (2012)
25. Korenevskiy, N.A., Skopin, D.E., Al Kasasbeh, R.T., Kuzmin, A.A.: System for studying specific features of attention and memory. Biomed. Eng. **44**(1), 32–35 (2010)
26. Al-Kasasbeh, R.T., Salman, A.M., Florin, I., Korenevskiy, N.: Modelling and parameter estimation for operator intelligence in man-machine systems. IJMIC Int. J. Model. Identif. Control **15**(1), 69–85 (2012). ISSN online 1746–6180
27. Al-Kasasbeh, R.T.: Software features for the estimation of an operators' group activity in man-machine system. Adv. Eng. Softw. **42**, 547–554 (2011). ISSN 0965-9978
28. Al-Kasasbeh, R.T., Ionescou, F., Mukattash, A., Btoush, R.: Confidence estimates of operators' group activity in man-machine systems. Jordan J. Mech. Ind. Eng. **4**(2), 324–329 (2010). ISSN 1995–6665
29. Al-Kasasbeh, R.T., El-tous, Y.: Selection of artifacts in EEG-signals using Kullback information. Eng. Sci. J. **22**, 69–77 (2006). ISSN 1687-0530
30. Al-Kasasbeh, R.T., Lvov, B.V.: Classification of EEG signals with artifacts, based on fractal dimension analysis, wavelet transform and neural network. Dirasat J. **32**, 78–90 (2005). ISSN 1560-4551
31. Al-Kasasbeh, R.T., Shapovalnikov, R.A., Skopin, D.E., Shamaseen, M.S.: Diagnosis of fetal state by ECG detection. Biomed. Eng. **43**(2), 84–89 (2009). ISSN 1573–8256
32. Al-Kasasbeh, R.T., Shamaseen, M.S., Skopin, D.E., Barbarawi, O., Geppener, V.V.: Automated detection of artifacts in electroencephalography signals using a linear prediction model. Biomed. Eng. **43**(1), 31–35 (2009). ISSN 1573–8256
33. Al-Kasasbeh, R.T., Shamaseen, M.S., Skopin, D.E.: Automated detection and selection of artifacts in encephalography signals. Biomed. Eng. **42**(6), 292–301 (2008). ISSN 1573–8256
34. Al-Kasasbeh, R.T., Shepovalnikov, R.A.: Two – dimensional representation spatial structure changes in brain bioelectric potential field. Appl. Bionics Biomech. J. **4**(1) (2007). ISSN 1754–2103
35. Al-Kasasbeh, R.T., Lvov, B.V.: Detection of eye movement and muscle artifact in EEG of normal subjects by classification of fractal dimension dynamics. Dirasat Int. J. **33** (2006). ISSN 1560-4551
36. Al-Kasasbeh, R., Korenevskiy, N., Ionescou, F., Alshamasin, M., Kuzmin, A.: Synthesis of fuzzy logic for prediction and medical diagnostics by energy characteristics of acupuncture points. J. Acupunct. Meridian Stud. **4**(3), 175–182 (2011)
37. Al-Kasasbeh, R.T., Korenevskiy, N.A., Ionescu, F., Kuzmin A.A.: Synthesis of combined fuzzy decision rules based on the exploration analysis data. In: Proceedings of 4th IAFA International Conference on Interdisciplinary Approaches in Fractal Analysis, pp. 71–78, Bucharest, Romania (2009). ISSN 2066-4451
38. Korenevsky, N.A., Krupchatnikov, R.A., Al-Kasasbeh, R.T.: Theoretical fundamentals of biophysics of acupuncture with applications in medicine, psychology and ecology on the basis of indistinct network models. Stary Oskol, TNT (2013). ISBN 978–5-94178-398-4
39. Al-Kasasbeh, R.T., Korenevskiy, N.A., Ionescu, F., Alshamasin, M.: Prediction and prenosological diagnostics of gastrointestinal tract diseases based on energy characteristics of acupuncture points and fuzzy logic. In: International Conference on Bioinformatics and Biomedical Technology, Sanya, China, pp. 307–312 (2011)
40. Korenevskiy, N.A., Al-Kasasbeh, R.T., Ionecou, F.: Prediction and prenosological diagnostics of heart diseases based on energy characteristics of acupuncture points and fuzzy logic. Comput. Methods Biomech. Biomed. Eng. **15**(7), 681–689 (2011)

41. Korenevskiy, N.A., Al-Kasasbeh, R.T., Alshamasin, M., Ionescou, F., Smith, A.: Prediction of gastric ulcers based on the change in electrical resistance of acupuncture points using fuzzy logic decision-making. Comput. Methods Biomech. Biomed. Eng. **16**(3), 302–313 (2013)
42. Korenevskiy, N., Alshamasin, M., Al-kasasbeh, R.T., Anatolevich, K.R., Ionescu, F.: Prediction and prenosological diagnosis of stomach diseases based on energy characteristics of acupuncture points and fuzzy logic. Int. J. Model. Identif. Control **23**(1), 55–67 (2015)
43. Al-Kasasbeh, R., Korenevskiy, N., Ionescu, F., Alshamasin, M., Smith, A.P., Alwadie, A., Aljbour, S.: Application of fuzzy analysis with the energy condition of bioactive points to the prediction and diagnosis of gastrointestinal tract diseases. Int. J. Biomed. Eng. Technol. **11** (2) (2013). ISSN online 1752–6426, ISSN print 1752-6418
44. Korenevskiy, N.A., Ionescu, Fl., Kuzmin, A.A., Al-Kasasbeh, R.T.: Synthesis of the combined fuzzy rules for medical applications with using tools of exploration analysis. J. Biomed. Electron. **5**, 65–76 (2009). ISSN 1560–4136
45. Korenevskiy, N.A., Ionescu, Fl., Kuzmin, A.A., Al-Kasasbeh, R.T.: Prediction of occurrence, aggravation and pre-nosological diagnostics of osteochondrosis of a backbone's lumbar region with use of reflexology methods. J. Biomed. Electron **5**, 60–64 (2009). ISSN 1560–4136
46. Al-Kasasbeh, R., Korenevskiy, N., Alshamasin, M.: Bioengineering system for prediction and early prenosological diagnostics of stomach diseases based on energy characteristics of bioactive points with fuzzy logic. In: 2nd Biomedical Engineering Conference and Expo, 30 November–01 December 2015, San Antonio, USA (2015)
47. Al-Kasasbeh, R.T., Ionescu, F., Korenevskiy, N.A., Mahdi, S.: Prediction and prenosological diagnostics of gastrointestinal tract diseases based on energy characteristic of acupuncture points and fuzzy logic. In: Proceedings of 3rd International Conference on Bioinformatics and Biomedical Technology, Sanya, China, 25–27 March 2011 (2011). 978-1-4244-9658-7/11/$26.00 C
48. Al-Kasasbeh, R.T., Ionescu, F., Korenevskiy, N.A., Mahdi, S.: Prediction and prenosological diagnostics of gastrointestinal tract diseases based on energy characteristic of acupuncture points and fuzzy logic. In: Proceedings of 3rd International Conference on Bioinformatics and Biomedical Technology, Sanya, China, 25–27 March 2011 (2011)
49. Korenevskiy, N.A., Ionescu, Fl., Kuzmin, A.A., Al-Kasasbeh, R.T.: The prognosis of early and differential diagnostics of diseases on the energetic dicbalance of Acupuncture points and fuzzy logic. In: Proceedings of 2009 International Conference Medical–Ecological Information Technologies, 26–29 May Kursk-Russia, pp. 155–169 (2009). ISBN 978-5-7681-0470-2
50. Kobzar, E.U., Al-Kasasbeh, R.T.: Prediction of occurrence of osteocchonrosis of backbone's lumbar region. In: Proceedings of 2009 International Conference on Medical–Ecological Information Technologies, 26–29 May Kursk-Russia, pp. 36–39 (2009). ISBN 978-5-7681-0470-2
51. Korenevskiy, N.A., Al -Kasasbeh, R.T., Ionecou, F.: Prediction and prenosological diagnostics of heart diseases based on energy characteristics of acupuncture points and fuzzy logic. Comput. Methods Biomech. Biomed. Eng. **15**(7), 681–689 (2012)
52. Korenevskiy, N.A., Al-Kasasbeh R.T., Ionescu F., Arghir, S.: Determining the level of psycho-emotional tension on a heterogeneous rules of fuzzy output. In: Proceedings of the 18th International Conference on Control Systems and Computer Science (CSCS - 18), 24–27 May 2011, Bucharest, Romania, pp. 901–904. Politechnica Press (2011)

53. Korenevskiy, N., Al-Kasasbeh, R.T., Ionescou, F., Alshamasin, M., Alkasasbeh, E., Smith, A.P.: Fuzzy determination of the human's level of psycho-emotional. In: Proceedings of the 4th International Conference on the Development of Biomedical Engineering, BME2012, Ho Chi Minh City, Vietnam, pp. 354–357 (2012)
54. Al-Kasasbeh, R.T., Korenevskiy, N., Alshamasin, M., Ionescou, F., Smith, A.P.: Prediction of gastric ulcers based on the change in electrical resistance of acupuncture points using fuzzy logic decision making. Comput. Methods Biomech. Biomed. Eng., 1–12 (2012). https://doi.org/10.1080/10255842.2011.618926
55. Al-Kasasbeh, R.T, Korenevskiy, N., Ionescou, F., Alshamasin, M., Kuzmin, A.: Prediction and prenosological diagnostics of heart diseases based on energy characteristics of acupuncture points and fuzzy logic. Comput. Methods Biomech. Biomed. Eng., 1–9 (2012). https://doi.org/10.1080/10255842.2011.554644
56. Al-Kasasbeh, R.T., Korenevskiy, N., Alshamasin, M.S., Klionskiy, D., Ionescu, F.: Numerical software algorithms for monitoring control processes and correcting health by synthesis of hybrid fuzzy rules of decision-making on the basis of changes in energetic characteristics of biologically active points. Int. J. Model. Identif. Control **25**, 119–137 (2016)
57. Al-Kasasbeh, R.T., Korenevskiy, N.A., Ionescu, F., Kuzmin, A.A.: Using fuzzy logic for prediction of occurrence, aggravation and prenosological diagnostics of osteochondrosis of a backbone's lumbar region. In: Proceedings of the IASTED International Conference Computational Intelligence, 17–19 August 2009, Honolulu, HI, USA, pp. 190–194. ACTA Press (2009)
58. AL-Kasasbeh, R.T., Korenevskiy, N., Alshamasin, M.S., Maksim, I.: Method of the ergonomics assessment of the technical systems and its influence on operators. In: Advances in the International Conference on Applied Human Factors and Ergonomics Human Factors and Ergonomics in Healthcare and Medical Devices (AHFE 2017), Part of the Advances in Intelligent Systems and Computing book series (AISC), 17–21 July, Los Angeles, CA, USA, vol. 590, pp. 581–592 (2017)

How to Improve Ancient Handcraft: The Bobbin Lace

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Abstract. Making an old handcraft in the same way since it already exists is a half way for killing it. A new style about it and a new perspective its necessary. Thinking on this important tradition characteristic, together with the local community from Peniche, in Portugal, we proposed new interventions and possibilities for renovated products.

Maintaining the real traditional technique and using the same instruments to make it, we proposed innovations by changing materials with the aim to produce new objects and renovated uses. With the application of the interventionist method, new products for different objects are proposed: cotton threads are abandoned and new materials to thread the bobbin lace are emerging. The traditional cotton towel is left behind, and contemporary products offer a renovated view on a traditional activity.

Keywords: Innovation · Bobbin lace · New materials

1 Introduction

Bobbin lace is a traditional activity of many women who live in Peniche. Peniche is located in the west coast of Portugal. Because of the location and the natural potential, the sea activities are well developed, namely fishing activities. Normally are the men who go to the sea, besides this, women have a choice for to stay at home or doing other activities. In the winter and when the fishing season is forbidden people were bound to look for another way to survive and increase their income. So, they chose assume like a lace maker, one way to face the hard time and have another ways to survival was doing the bobbin lace.

Bobbin lace is an activity close to the fishing activity. The closeness of the fishing nets and the knots of lace could show this proximity. A popular saying explains something like: “where are the fishing activities there are lace”. So, in the hard time to fish, they invested on doing the bobbin lace.

The activity of doing lace is more than 500 years old. Because of it we don’t know the real origin of the bobbin lace. Along the years there was no changes to the way of doing this kind of lace, not even changed the materials that they use. And there isn’t significant change at the products produced along the years [1].

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2 The Bobbin Lace

Bobbin lace is a textile material that is handmade and presents varying designs and interlacing along its surface. It is a material which is produced on more or less extensive surfaces and which has a lacy aspect which is characteristic of this type of technique. Produced taking into account the interweaving of warp and weft yarns, this technique provides the possibility of letting some yarn rest and use others to perform part of the textile surface, after which later we can resume weaving with all or others warp and weft yarns, allowing the realization of possible effects only by hand (Fig. 1).

Fig. 1. Traditional bobbin lace. Photograph taken on 13 April 2017. Source: the author

For making bobbin lace specific materials are required. The bobbins, the instrument that give the name to the technique, can be quite different, depending on the places where the lace is made and also on the wealthy status of each lace maker. In Peniche the bobbins are made of wood, has a shape like a pear, with a little ball at the end, it needs to have the weight enough to hold the thread. Others required materials is the bolster cushion, the bench to hold the cushion in place, the pricking card and threads. Mostly the products made with the technique of bobbin lace are made with the one hundred percent cotton thread. They choose this material by considering it as an easy material to weave and can be washed and ironed easily. "… a craft object must be made substantially by hand, utilizing the hand itself, hand tools, and to some degree, power tools" [2]. Because of this we think on maintaining the technique like it is but changing the used materials.

However, using the same material along these years can just bring the same results, and in the same way, they produce the same products along these years. Comparing with some years ago, people don't consume the same things they consumed years ago.

Thinking at the new kind of consumers, living in a different way and looking for new things that bring new sensations and emotions, we bring trough the bobbin lace new possibilities for renovated products and aesthetics. The technique used for weaving the bobbin lace new products are the traditional one, but radically we propose to change the materials used for weaving, and the use purpose of the new objects.

"In essence, contemporary art textiles share two dominant strategies with other areas of visual-art practice, namely an interest in exploring visual metaphor in order to make comment upon or allude to social or political issues, and an interest in using textile art to comment on the nature of the art itself" [2].

The first material that we introduce is the wire: copper wire, silver wire and gold wire. Weaving with this material is a little more difficult if we compare with the cotton yarn, but even is possible. The lace makers made the most important and traditional stitches from Peniche (Fig. 2).

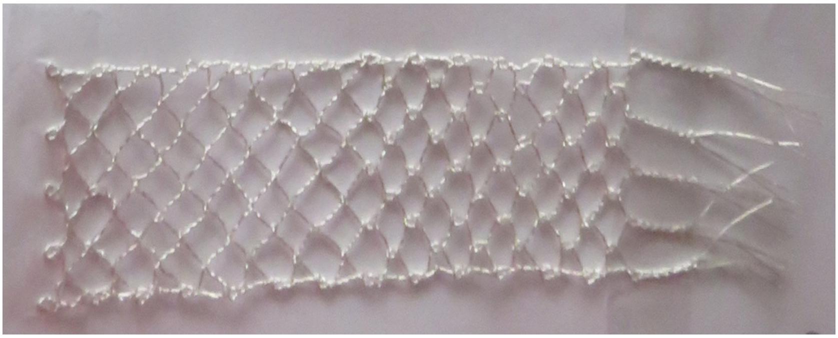

Fig. 2. Silver wire test. Test performed with silver thread. Photograph taken on 20 April 2016. Source: the author

Through this test we can think in another objects and applications we can apply the new material. It can be made on big scale to be used like decorative in some environments, outdoors or indoors. It can be used in jewellery creating rings, bracelets, necklaces and so one, or even introduce precious stones inside the lace. The use as a authentic jewellers like author's jewellery is also a possibility.

The designer has technical knowledge about materials and production techniques and serves as the facilitator between the product and the material, making tangible and improving the local identity products. According to Lima (2015), the relation and the work carried out jointly between the designer and the lace maker are important because the artisan must be seen as protagonists and not just supporting, that is, labour without creative autonomy, would lead to the proletariat of the craftsman [3].

In this relationship with the bobbin lace of Peniche and the introduction of new materials, it is necessary to make the bridge with a specialist in bobbin lace weaving. However, the material for the warp needs to be carefully chosen, taking into account that not all materials are possible to be woven because of the specific knots of the bobbin lace technique, and others, could completely change the identity of the bobbin lace from Peniche.

This revolution, modification or transformation has to be intend as innovation, where ancient techniques are associated to new materials and renovated needs. According to Stoneman, innovating means arranging and introducing novelties, products never seen or marketed "innovation in a 'global' sense is defined to occur when new products, processes, raw materials, and management methods are first introduced to an existing or new market" [4].

The complexity, shorter life cycles of products and increasingly variable market demands make it imperative to develop new products [5]. The world is constantly changing, and we need to re-think manners and products that already exist but are considered old and to adapt to present uses and way of living.

Innovations need to think, always, in bringing new and good emotions. So, the innovative products become superior when they are value-added and bring benefit to users. Products that meet the needs of users and at the same time facilitate their life are considered successful products. In the same way, one can speak of the products that trigger emotional ties like this traditional activity" [6].

Another product that could bring innovation is to weave the bobbin lace with another fibres: carbon fibre, glass fibre and ceramic fibre. They are malleable wire and the lace maker did with them easily, using the most popular stitches of Peniche.

Looking at the Figs. 3 and 4 above, it is clearly possible to renew materials to weave with the technique of bobbin lace. So, the lace maker can use the same technique but changing the traditional cotton fibre to innovation materials.

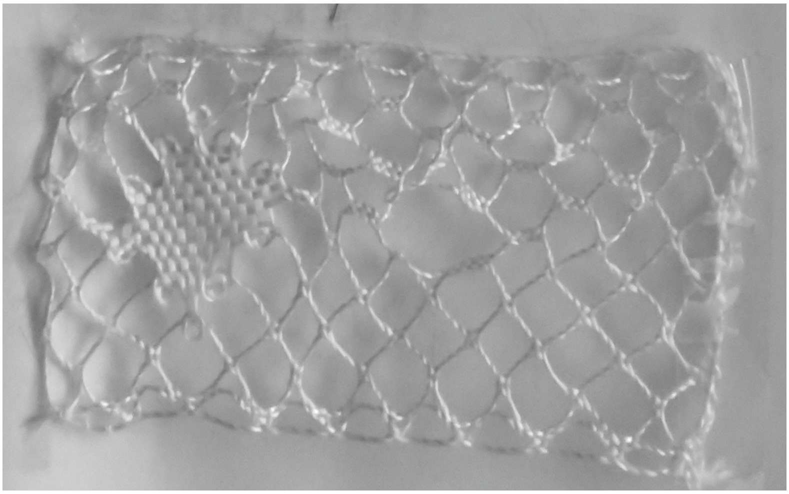

Fig. 3. Test performed with glass fibre thread. Photograph taken on 15 July 2016. Source: the author

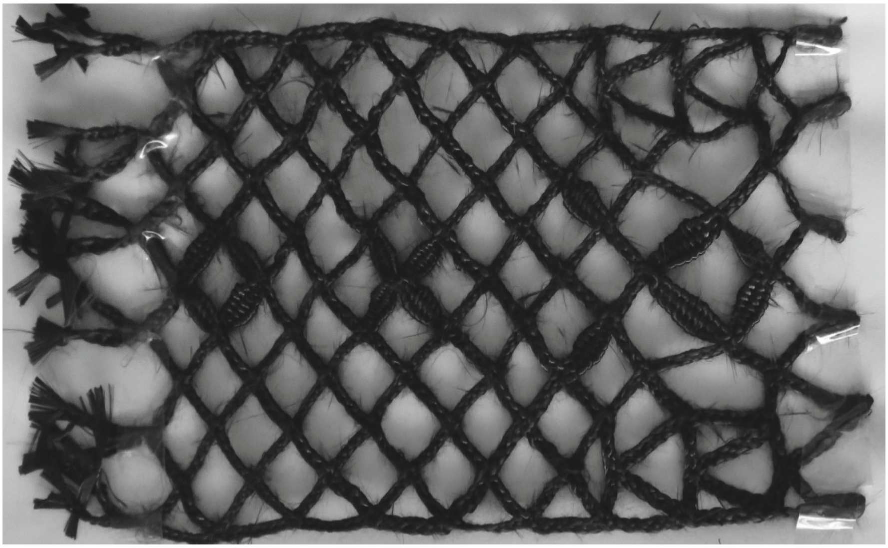

Fig. 4. Test performed with carbon fibre thread. Photograph taken on 15 July 2016. Source: the author

Thinking on the characteristics of the glass fibre and the carbon fibre we observe that both materials are resistant to high temperatures. So, we can associate to a third material that work in a high temperature, like glass. Through this we did a new experience. Fusing the carbon fiber with two glass plates. We can show the result (Fig. 5).

Fig. 5. Carbon fiber between two plates of glass. Test. Photograph taken on 27 April 2017. Source: the author

Looking for the fusing of new materials, suggestions to create for design decoration, among others are numerous and objects for interior and exterior design are almost endless.

"Innovation is about knowledge – creating new possibilities through combining different knowledge sets. These can be in the form of knowledge about what is technically possible or what particular configuration of this would meet an articulated or latent need. Such knowledge may already exist in our experience, based on something we have seen or done before. Or it could result from a process of search – research into technologies, markets, competitor actions, etc. And it could be in explicit form, codified in such a way that others can access it, discuss it, transfer it, etc. – or it can be in tacit form, known about but not actually put into words or formulae" [7].

Making new products from one product that has low offer we made a increase, a value increase, to all people involved in this tradition. A tradition that will be easily forgotten if we don't optimize it. Creating a new view, a new possibility of perspective to something that would die along the years.

"And it is change that always provides the opportunity for the new and different. Systematic innovation therefore consists in the purposeful and organized search for changes, and in the systematic analysis of the opportunities such changes might offer for economic or social innovation" [8].

With this innovation we can create a new life for the bobbin lace and for the lace makers, for the people who lives and believe on it. New products with history and meaning are coming.

3 Conclusions

In this work the importance of innovation in artisanal and traditional products was clear. In an increasingly globalized era, the importance of cultural identity expressed through the objects, that surround us and which form part of our collective memory, reinforces our individuality at the same time as our belonging to a specific group. The renewal of the language used in the proposed objects provides the use of an ancestral technique in renewed products that, presenting themselves as current and approaching new aesthetics and uses, promotes the diffusion and the recognition in modern key of elements of the history itself and traditional and contemporary culture. The materials proposed for the experimentation are innovative materials in this type of application, presenting a renewed aesthetic and the possibility of using the income realized not only as final material but as an intermediate element that allows the exploration of new technical possibilities and renewed functionalities.

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References

1. Calado, M.: História da Renda de Bilros de Peniche (Autor ed.). Gráfica Torriana, Peniche (2003)
2. Dormer, P.: The Culture of Craft - Status and Future. Manchester University Press, Manchester (1997)
3. Lima, M.F.: Design e Artesanato: relações de poder. 5º Simpósio de Design Sustentável, pp. 11–20. Rio de Janeiro (2015)
4. Stoneman, P.: Soft Innovation - Economics, Product Aesthetics, and the Creative Industries. Oxford University Press, Oxford (2010)
5. Cooper, R., Aouad, G., Lee, A., Wu, S., Fleming, A., Kagioglou, M.: Process Management in Design and Construction. Blackweel, Oxford (2005)
6. Cooper, R.G.: From experience - the invisible success factors in product innovation. J. Prod. Innov. Manage **16**, 115–133 (1999)
7. Tidd, J., Bessant, J., Pavitt, K.: Managing Innovation - Integrating Technological, Market and Organizational Change, 3rd edn. Wiley, Chichester (2005)
8. Drucker, P.F.: Innovation and Entrepreneurship - Practice and Principles. HarperCollins Publishers, New York (2002)

The Need for Ergonomic Studies for the Reduction of Injuries and Redesign of Tools in the Agricultural Sector Through TRIZ

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Abstract. The importance of the prevention of ergonomic risks in the agricultural sector makes it necessary to carry out studies and have adequate tools to reduce them. Accidents related to inadequate ergonomic conditions at work in the field, whether in agricultural or livestock activities, are considered as factors that affect productivity. The aim of this study is to describe the importance of ergonomic risk prevention in the development of multinutritional blocks for cattle in the Huasteca area in north of Veracruz, Mexico. Using the Rapid Upper Limb Assessment Methods (RULA), Rapid Entire Body Assessment (REBA) and Job Strain Index (JSI) a group of people dedicated to the livestock sector, were evaluated in order to determine ergonomic risk indexes. With the use of the Theory of Inventive Problem Solving (TRIZ), was designed an ergonomic compactor that reduces over stress and possible injuries, allowing the worker to perform his task easily and comfortably.

Keywords: Anthropometry · Musculoskeletal disorders · Ergonomic design TRIZ

1 Introduction

Currently musculoskeletal disorders (MSD) and other health risks at work in agriculture have been recognized in several studies in scientific literature, work-related MSD have been recognized as having multiple causes, such as bad posture, repetitive and forceful activities [1].

Studies have shown that agriculture is associated with many agricultural workers who experience low back pain (low back pain). The rehabilitation of these workers should facilitate their functioning, activities and level of participation in an adequate manner [2].

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A recent review of (MSD) among farmers reported 91% lifetime prevalence for any type of MSD and a one year prevalence of 77% [3].

There are very few investigations of ergonomics applied to the Mexican agricultural sector, and almost none on the development of machinery or tools to facilitate the tasks that avoid bad postures or long-term injuries. Workers in the livestock sector produce their agricultural products with inadequate techniques, their processes are slow and they become uncomfortable and insecure.

Studies of many geographical environments and agricultural products show that disorders of the lower back are a major public health problem among farmers, who represent a special rural population. However, few studies have examined the impact of lumbar disorders on the work of farmers or the strategies they adopt to avoid associated pain and disability [4]. In this sense, in the search for quality and productivity in this sector implies the need to develop studies that generate improvements in the design of tools and jobs, greater safety and reduction of injuries, which will generate an increase in the satisfaction of the workers of countryside.

In Korea, many studies have investigated occupational hazards using ergonomic risk assessment tools to prevent musculoskeletal disorders. The most common assessment tools include REBA (rapid assessment of the whole body), RULA (rapid assessment of upper limb), OWAS (Ovako work posture analysis system), PATH (posture, activity, tools and management) and OCRA (repetitive occupational action) These ergonomic assessment tools focus on the position of the upper extremities rather than the lower extremities, and do not apply well to the agricultural, manufacturing or construction sectors. Therefore, these tools are unable to address the continuous increase in skeletal disease, particularly in agricultural workers [5].

To solve this problem TRIZ was used, that is a methodology of systematic innovation and most complete creativity ever developed. Its main objective is to solve unconventional problems and forecast future technologies and products, but it also provides a method to face reliability problems [6].

The identification and adequate resolution of system compensations or the effective evaluation of alternatives is a key product of systems engineering. Without adequate resolution, system performance is hampered or non-optimal technologies are chosen. TRIZ, the Theory of Inventive Problem Solving, offers tools and methods to identify and resolve compensations (which refer to contradictions or conflicts) [7].

As agricultural sector is one of the most punished sectors in the field of MSDs, this study propose the redesign of a tool to reduce injuries since currently many of the tools or machinery suitable for carrying out some daily tasks do not have an ergonomic design. Identifying and appropriately resolving system tradeoffs or effectively evaluating alternatives is a key deliverable of systems engineering.

2 Background

In West Bengal, India, to evaluate musculoskeletal disorder (MSD), thermal stress, and physiological stress A total of 70 male potato cultivators were selected randomly; Rapid Entire Body Assessment method (REBA) was used and the study shown that

Most of the participants suffered discomfort at different parts of the body, especially in the lower back, knee, ankle, and feet regions [8].

In population based studies, MSDs were more frequent among farmers, with more severe symptoms affecting the hands and forearms, low back, and hips compared to less physically demanding nonfarmer occupations. The impact of MSDs in farmers is substantial and results in long-term disability and income loss [9].

Studies reveal Farmers are vulnerable to a range of MSDs including: osteoarthritis of the hip and knee, low back pain (LBP), upper limb disorders, and hand/arm vibration syndrome, as well as to the consequences of trauma such as sprains, fractures, and dislocations and almost 60% of Southeast Kansas farmers reported that they experienced a farm work-related MSD symptom during the previous 12 months [10].

In Sao Paulo, Brazil, studies showed a correlation between the parameters of classical TRIZ and variables of analysis of the Ergonomic Work Analysis (EWA) to construct a matrix of contradictions in ergonomics, with the objective of assisting the designing processes in the Brazilian agricultural sector [11].

3 Methods

An anthropometric study was carried out to a group of workers of the agricultural sector dedicated to the livestock sector and who elaborate multinutritional blocks for cattle. The age of people in the population between 18 and 60 years all of them were males and their level of education are among middle school.

The postures and physical load were evaluated during the working day with the RULA, REBA and JSI methodologies in order to determine ergonomic risk indexes. The objective of this evaluation was to design a device with the help of TRIZ for the compaction of multinutritional blocks in order to reduce physical effort and reduce or eliminate injuries or musculoskeletal disorders (Table 1).

Table 1. Anthropometric data considered in the study

Maximum vertical reach with grip	Elbow-foot length
Maximum vertical reach without grip	Arm length
Eye height	Forearm length
Shoulder height	Popliteal Height and Buttock popliteal height

Ergonomic evaluation is performed by RULA to evaluate the upper body (neck, arms, forearms, wrists and legs) of workers during the compaction of multinutritional blocks process. After that, the evaluation was made with REBA and JSI.

The method of application of RULA and REBA method is as follows:

1. Determine cycle times and observe the worker for several of these cycles
2. Select the bids will be evaluated
3. Determining, for each position, if the left and right side or be evaluated (in case of doubt both will be assessed)

4. Determine the scores for each body part
5. Get the final score of the method and Performance Level to determine the risk stocks
6. Check the scores of the different body parts to determine where you need to apply corrections
7. Redesigning the post or changes to improve posture if necessary
8. If you have made changes, reassess the position with RULA method to check the effectiveness of the improvement (Fig. 1).

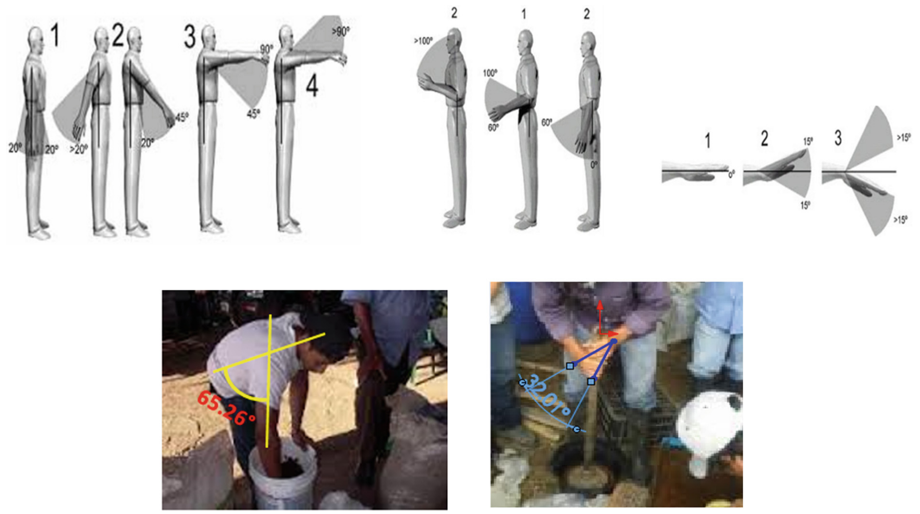

Fig. 1. RULA method: arm, forearm and wrist

JSI is a method for estimating the risks of injury risks to the wrists and hands based upon assessments of force, repetition, posture and duration (Fig. 2 and Table 2).

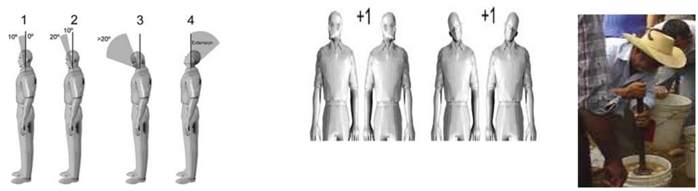

Fig. 2. RULA method: neck position

Table 2. JSI ratings

Intensity of Exertion (IE)
Duration of Exertion (DE)
Efforts/Minute (EM)
Hand/Wrist Posture (HWP)
Speed of Work (SW)
Duration per Day (DD)

4 Results

The RULA method mentions that the overall scores obtained in groups A and B will be modified depending on the type of muscle activity developed and the force applied during the task. In this case the activity that is carried out has repetitive movements and makes considerable efforts, the assigned score for this is 2 (Fig. 3).

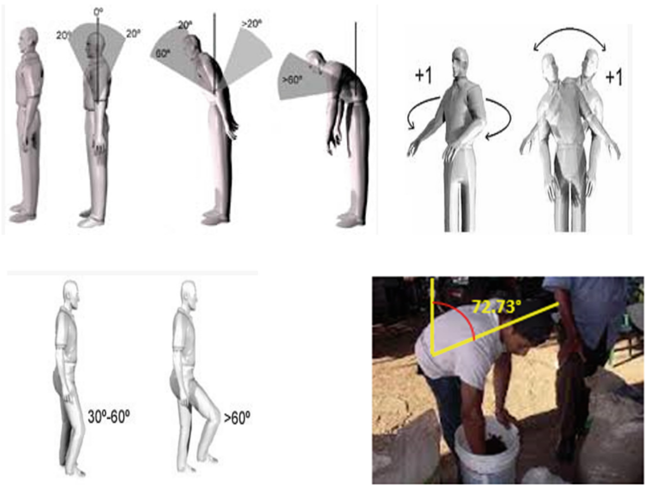

Fig. 3. REBA method: trunk and leg position

In order to obtain the final score, the group A score is considered and the score corresponding to the muscular activity is added and that due to the applied forces will be called C score, doing the same with group B, its global score will be taken and the muscle activity and the applied forces will be added, calling this score D. The final score will be 7, that means high risk and implement changes (Table 3).

The REBA method is very similar to the RULA method previously presented, with the variant that this method values the lower part of the body a little more in detail. In this case, a high level was obtained, (11–15) which suggests acting immediately to prevent even greater risks (Table 4).

Table 3. JSI guidelines for assigning a rating criterion

Rating criterion	% MSA	Borg scale B	Perceived effort
Light	<10%	<=2	Barely noticeable or relaxed effort
Somewhat hard	10%–29%	3	Noticeable or definite effort
Hard	30%–49%	4–5	Obvious effort; unchanged facial expression
Very hard	50%–79%	6–7	Substantial effort; changes facial expression
Near maximal	>=80%	>7	Uses shoulder or trunk to generate force

Moore, J.S. and Garg, A. (1995) American Industrial Hygiene Journal 56:443-58 [12].

Table 4. REBA level of MSD risk

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**

The results obtained are shown when applying the JSI method to the upper, which was applied to workers in charge of the compaction activity of multinutritional blocks. The evaluation was applied for the moment in which the compaction is carried out exclusively (Table 5).

Table 5. Stress index calculation

Intensity of Exertion (IE)	6
Duration of Exertion (DE)	3
Efforts/Minute (EM)	3
Hand/Wrist Posture (HWP)	2
Speed of Work (SW)	1.5
Duration per Day (DD)	0.5

$$JSI = IE \text{ x } DE \text{ x } EM \text{ x } HWP \text{ x } SW \text{ x } DD \tag{1}$$

JSI values less than or equal to 3 indicate that the task is probably safe. Scores greater than or equal to 7 indicate that the task is probably dangerous. In general, scores higher than 5 are associated with musculoskeletal disorders of the upper extremities (Fig. 4).

Results Key			
	SI ≤ 3	Job is probably safe	
Results Key	3 < SI < 7	Job may place individual at increased risk for distal upper extremity disorders	81
	7 ≤ SI	Job is probably hazardous	

Fig. 4. JSI results

TRIZ is a structured methodology for innovation, it examines the problems of inventiveness methodically, exploring fields or spaces of general solutions for the creation of ideas. TRIZ consists of tools that will help generate an ideal final result (Fig. 5).

Improve	1	26	27	28	29	30
1	/	3,26,18,31	1,3,11,27	28,27,35,26	28,35,26,18	22,21,18,27
2	*	19,6,18,26	10,28,8,3	18,26,28	10,1,35,17	2,19,22,37
3	8,15,29,34	29,35	10,14,29,40	28,32,4	10,28,29,37	1,15,17,24
4	*	*	15,29,28	32,28,3	2,32,10	1,18
5	2,17,29,4	29,30,6,13	29,9	26,28,32,3	2,32	22,33,28,1
6	*	2,18,40,4	32,35,40,4	26,28,32,3	2,29,18,36	27,2,39,35
7	2,26,29,40	29,30,7	14,1,40,11	25,26,28	25,28,2,16	22,21,27,35
8	*	35,3	2,35,16	*	35,10,25	34,39,19,27
9	2,28,13,38	10,19,29,38	11,35,27,28	28,32,1,24	10,28,32,25	1,28,35,23
10	8,1,37,18	14,29,18,36	3,35,13,21	35,10,23,24	28,29,37,36	1,35,40,18
11	10,36,37,40	10,14,36	10,13,19,35	6,28,25	3,35	22,2,37
12	8,10,29,40	36,22	10,40,16	28,32,1	32,30,40	22,1,2,35
13	21,35,2,39	15,32,35	*	13	18	35,24,30,18
14	1,8,40,15	29,10,27	11,3	3,27,16	3,27	18,35,37,1
15	19,5,34,31	3,35,10,40	11,2,13	3	3,27,16,40	22,15,33,28

Fig. 5. Technical contradiction matrix [13]

Giving solution to the ergonomic problems previously showed, and through the identification of technical contradictions with the use of matrix Triz, it was proposed a prototype compactor of multinutrient blocks for cattle population, the purpose of this device is reduce the effort and thus physical injuries or musculoskeletal injuries that occur in the long term worker (Fig. 6).

The TRIZ parameters used are:

Parameter A: 10. Force (Reduce the worker force)
Parameter B: 29. Precision/Accuracy of manufacturing (improve compaction)

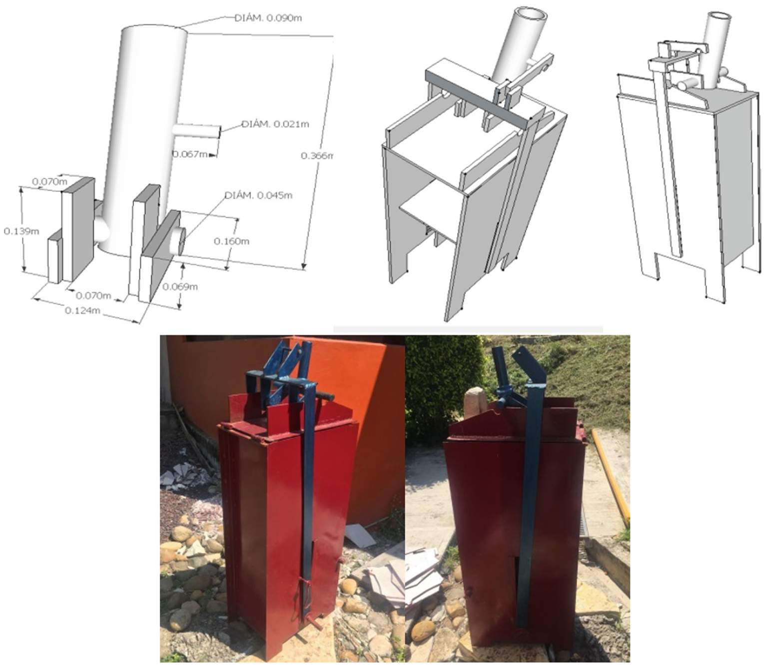

Fig. 6. Multi-nutritional block compaction prototype

The inventive principles of TRIZ used are:

- 28. Mechanical interaction substitution
- 29. Pneumatics/Hydraulics
- 37. Thermal expansion
- 36. Phase Transition

As a result of the application of the inventive principles of the contradictions matrix, a multi-nutritional block compaction prototype was developed.

Considering the principle of leverage and calculating the moment of the pressure that is exerted when applying force at the other end, the use of this principle is proposed to prevent the worker from overexerting himself and adopting a bad posture.

5 Discussion

With the development of the compactor prototype based on the principles of inventiveness of TRIZ, the worker will perform the activities and processes more quickly with less effort, since doing it manually as it is done today, without the help of an ergonomic tool causes wear and tear physical, injuries and illnesses as shown by the evaluation with the RULA, REBA and JSI methods. In the North of Veracruz, Mexico, the inhabitants carry out these activities with their hands and rudimentary tools with the risk of generating injuries in the spine, back, knees, hands, neck and shoulders.

Studies made in India showed that male potato cultivators suffered severe pain in different parts of the body, especially in the lower back, neck, shoulder, and knees of the body because of awkward postures being held for prolonged periods of time. These hamper their normal physical activity and productivity [8].

In Korea agricultural work involves labor-intensive practices and is related to a multitude of MSD risk factors. There have been some interventions to reduce the demand for labor intensive practices and to improve working efficacy in an effort to reduce the risk of MSDs [9].

In Brazil a study with TRIZ was made using Technical contradictions matrix giving a result the correlation between the parameters of classical TRIZ and categories of analysis of the EWA, in order that the can be used in designing processes that involves requirements of ergonomics, with the intention that the risk factors can be dealt with by equating the criteria for health and productivity, often conflicting [11].

Future Research

Future research needs to analyses the prototype with the same group of workers and applied RULA, REBA and JSI method to prove that obtains results are favorable with the use of the compactor, generating a decrease in injuries and increase in productivity.

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References

1. Jain, R., Meena, M.L., Dangayach, G.S.: Ergonomic intervention for manual harvesting in agriculture: a review. In: Ergonomics in Caring for People: Proceedings of the International Conference on Humanizing Work and Work Environment, p. 183. Springer (2017)
2. Ganesh, S., Chhabra, D., Kumari, N.: The effectiveness of rehabilitation on pain-free farming in agriculture workers with low back pain in India. Work **55**(2), 399–411 (2016)
3. Trask, C., Bath, B., Milosavljevic, S., Kociolek, A.M., Predicala, B., Penz, E., Whittington, L.: Evaluating swine injection technologies as a workplace musculoskeletal injury intervention: a study protocol. BioMed Research International (2017)
4. Trask, C., Bath, B., Johnson, P.W., Teschke, K.: Risk factors for low back disorders in Saskatchewan farmers: field-based exposure assessment to build a foundation for epidemiological studies. JMIR Res. Protoc. **5**(2), e111 (2016)
5. Kong, Y.K., Lee, S.Y., Lee, K.S., Kim, D.M.: Comparisons of ergonomic evaluation tools (ALLA, RULA, REBA and OWAS) for farm work. Int. J. Occup. Saf. Ergon. **24**, 1–6 (2017)
6. Regazzoni, D., Russo, D.: TRIZ tools to enhance risk management. Procedia Eng. **9**, 40–51 (2011)
7. Blackburn, T.D., Mazzuchi, T.A., Sarkani, S.: Using a TRIZ framework for systems engineering trade studies. Syst. Eng. **15**(3), 355–367 (2012)
8. Das, B., Gangopadhyay, S.: Prevalence of musculoskeletal disorders and physiological stress among adult, male potato cultivators of West Bengal. India. Asia Pac. J. Public Health **27**(2), NP1669–NP1682 (2015)

9. Jo, H., Baek, S., Park, H.W., Lee, S.A., Moon, J., Yang, J.E., Kim, K.S., Kim, J.Y., Kang, E. K.: Farmers' cohort for agricultural work-related musculoskeletal disorders (farm) study: study design, methods, and baseline characteristics of enrolled subjects. J. Epidemiol. **26**(1), 50–56 (2016)
10. Osborne, A., Blake, C., Fullen, B.M.: Prevalence of musculoskeletal disorders among farmers: a systematic review. Am. J. Ind. Med. **55**(2), 143–158 (2012)
11. Tosetto, T., Camarotto, J.A.: Ergonomics and design in the Brazilian agricultural sector: a proposal to build matrix of contradictions. Work **41**(Suppl. 1), 5339–5346 (2012)
12. Moore, J.S., Garg, A.: The strain index: a proposed method to analyze jobs for risk of distal upper extremity disorders. Am. Ind. Hyg. Assoc. J. **56**(5), 443–458 (1995)
13. Bukham, I.: TRIZ Technology for Innovation, Editorial Cubic Creativity (2012)

A Postural Analysis of Rice Farming in San Miguel, Bulacan

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Abstract. Hazards of rice farming in the Philippines are greatly understudied despite its increased risk of work-related musculoskeletal disorders due to its heavy reliance on manual methods. This study aims to examine the presence of WMSD symptoms in Filipino farmers and assess the level of risk associated to the farming activities through postural analysis. Fifteen (15) farmers were interviewed using a revised Nordic Musculoskeletal Questionnaire. Rapid Entire Body Assessment (REBA) was used to assess the postures when carrying out farming tasks. Results of the interview showed that most farmers perceive pain in the shoulders (86.67%) and hips (73.33%) during the last 12 months, in the upper back (33.33%), and wrist/hand (26.67%) in the last 7 days. REBA scores of the postures performed by farmers ranged from medium to very high risk, indicating immediate action is necessary. Results also showed that there exists high correlation between REBA scores and perceived body pain.

Keywords: Postural analysis · Ergonomics · Agriculture · Rice farming REBA · Nordic Musculoskeletal Questionnaire (NMQ) · WMSDs

1 Introduction

1.1 Background of the Study

Rice is the Philippines' most important staple crop: "it comprises 20% of the gross value added (GVA) of Philippine agriculture and employs 2.5 million households, broken down into 2.1 million farmers, 110,000 workers for post-farm activities, and 320,000 for ancillary activities" [1].

Rice farming is an arduous job - it is an occupation that involves strenuous effort that is both physically and mentally demanding. Several steps must be accomplished before the final output is produced such as land preparation, seedbed preparation, planting, and finally, harvesting. Each step requires tasks that subject farmers to bad biomechanics such as excessive lifting, bending, twisting, pushing and pulling [2].

The nature of a rice farmer's job exposes them to several health risks such as musculoskeletal disorders. Musculoskeletal disorders (MSDs) are injuries and disorders that affect the musculoskeletal system, i.e. the muscles, tendons, ligaments, nerves, etc.

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[3] whose main causes are frequent overexertion of soft tissues, awkward postures, and repeated tasks [4]. Despite the significant amount of people in rice farming and all its contributions, the hazards and risks of farming in the Philippines are greatly understudied and underexplored. Therefore, merely reinforced by the irrefutable importance of Filipino rice farmers, it is of utmost importance that their working conditions be assessed in order to ensure their safety, health, and well-being.

1.2 Rationale of the Study

Agricultural mechanisation has yet to be established in the Philippines. Despite being the 8th largest producer of rice [5], it remains to be one of the least mechanised in terms of rice farming compared to its Southeast Asian neighbours due to financial constraints [6]. This translates to majority of Filipino farmers still relying heavily on manual methods in performing all the tasks farming entails exposing them to risks of MSDs.

This is a pressing concern for the country's farming community. When the average age of Filipino farmers is 57 [7], developing a MSD will be but a burden on them and their job because aside from medical treatment costs, MSDs have a high cost in terms of workdays lost [8]. With the harrowing fact that Filipino farmers are amongst the country's poorest [9] and that the Philippine retirement age is 60, there is an increased likelihood of them simply disregarding and paying no heed to the risk of MSDs. Such attitude is undesirable because MSDs in the elderly should be diagnosed immediately as delayed treatment is associated with increased morbidity and mortality [10].

Prevention is better than cure. Considering all these health risks, the probable course of action of the farmers, and the consequences of the probable course of action, it becomes *imperative* to investigate the probable risks leading to the development of MSDs in farmers. One way to tackle this is to conduct a postural analysis of rice farming to identify the sources of such risks and address them accordingly.

1.3 Scope and Limitations

The study is focused on a private commercial rice farm located in San Miguel, one of the largest rice towns in the province of Bulacan. The fifteen (15) farmers of the farm, who are responsible for most, if not all, daily farming activities in the land area, are the primary subjects of the study. Given the timeline of farming tasks (i.e. not all farming tasks are performed simultaneously), the tasks analysed for posture only include: plowing, harrowing, leveling, seedbed preparation, planting, reaping, hauling, and threshing.

This study is limited to a postural analysis of farming tasks using Rapid Entire Body Assessment (REBA) and its corresponding statistical analysis. Only risks from posture in the development of MSDs are considered; any other risks (e.g. vibration from the machine) and/or factors are not included.

2 Methodology

The primary objective of the study is to assess the activities of the farmers through a postural analysis using Rapid Entire Body Assessment (REBA). The study also investigates the cases of perceived body pain in relation to its corresponding specific REBA Score.

1. A sample of fifteen farmers from San Miguel, Bulacan were asked to participate in the study;
2. The participants were interviewed using a modified Nordic Musculoskeletal Questionnaire (NMQ). Personal information such as age; duration of work; intensity, frequency, interference of pain to their work activity; and most difficult task performed [Cornell] were also asked;
3. The farmers performing the following tasks (Plowing, Harrowing and Leveling using a hand tractor, Harrowing and Leveling with the aid of a carabao, Seedbed Preparation, Planting, Reaping, Hauling, Threshing) were then documented through side-view videos and images to assess postural risk factors.
4. The videos and images per task were then scored according to the Rapid Entire Body Assessment (REBA) evaluation tool. This was done to know the potential risk of acquiring work-related musculoskeletal disorders from doing each task. The corresponding action levels per posture were then concluded.

3 Results and Discussion

The REBA scores of the majority of the tasks (excluding threshing) indicate that there are high to very high MSD risk levels in performing the task (see Table 1). This shows that the action required from all tasks should be investigated and change should be implemented soon. Threshing is the only task with medium risk level of developing MSD, but change is still necessary to lower the risk levels in performing this activity.

Table 1. REBA scores for tasks

Activities	Ave. REBA score	Conclusion
Plowing (Rotovator)	9	High Risk
Harrowing & Leveling (Hand Tractor)	12	Very High Risk
Harrowing & Leveling (Manual)	12	Very High Risk
Seedbed Preparation	13	Very High Risk
Planting	12	Very High Risk
Reaping	10	High Risk
Hauling	14	Very High Risk
Threshing	5	Medium Risk

To analyze the result of the survey, perceived pain experienced when performing each activity was computed by multiplying the average intensity and average frequency of pain each of the 15 farmers experienced. Table 2 below shows the product of average frequency and average intensity associated with each task and its corresponding REBA scores. Hauling had the highest level of perceived pain (Frequency X Intensity) also received the highest REBA score.

Table 2. Frequency x Intensity of Pain vs REBA

Activities	Ave. frequency x Ave. intensity	REBA
Plowing (Rotovator)	2.67	9
Hand tractor	3.48	12
Manual leveling	3.58	12
Seedbed	2.03	13
Planting	5.74	12
Reaping	6.76	10
Hauling	7.47	14
Threshing	2.20	5

The total number of participants that had trouble in the specific body parts during the last 12 months and last 7 days is presented in Table 3. Parts that most farmers perceive pain were in the shoulders (86.67%) and hips (73.33%) during the last 12 months. This is consistent with other literature that specify the shoulders and lower back as the most prevalent body parts that experience musculoskeletal discomfort .

Table 3. % of population perceived body pain

Percentage	12 months	7 days
Neck	53.33	20.00
Shoulders	**86.67**	**20.00**
Chest	26.67	20.00
Upper back	46.67	33.33
Middle back	26.67	13.33
Lower back	53.33	13.33
Wrist/Hand	53.33	26.67
Hips	**73.33**	**20.00**
Thighs	53.33	20.00
Knees	40.00	13.33
Calves	60.00	13.33
Feet	40.00	13.33
Average age (Years)	41.93	
Ave. length of work (Years)	18.00	
No of stopped work (Percentage, of 15)	53.33	
Bad posture (Slouching) (Percentage, of 15)	40.00	

The most prevalent body pain experienced in the last 7 days were in the upper back and wrist/hand with 33.33% and 26.67% of the population, respectively. This may indicate that perceived wrist/hand pains are experienced only for short periods of time while shoulder and upper back pain are consistent in both short and long term personal evaluation.

The researchers cross-checked the REBA scores per part per task with the percentage of the population that experience pain for each body part. It can be observed that the upper arm and trunk had the highest REBA scores among all body parts. This is consistent with the high percentage of farmers that experience pain in those body parts, backing up the theory that higher REBA scores indicate higher risk of body pain (Table 4).

Table 4. Average specific REBA scores per body part

Activities	Neck	Trunk	Legs	Upper arm	Lower arm	Wrist
Plowing	0.67	0.8	0.25	0.5	1	0.67
Harrowing & Leveling (Hand Tractor)	1	1	0.5	0.83	0.5	0.67
Harrowing & Leveling (Manual)	1	0.8	0.75	0.5	0.5	0.67
Seed preparation	0.67	1	1	0.83	1	0.67
Planting	0.67	1	0.75	0.83	1	0.33
Reaping	0.33	1	0.5	0.83	0.5	0.67
Hauling	1	0.8	0.75	0.83	1	0.67
Threshing	0.67	0.4	0.5	0.33	0.5	0.33
Average	0.75125	**0.85**	0.625	**0.685**	0.75	0.585

4 Conclusion

Most of the farming activities garnered high REBA scores in the 11+ range, revealing a dire necessity to improve these activities as they pose severe health risks to the farmers.

From further analysis, it was shown that areas with the highest potential onset of WMSDs were the shoulders and hips. This is consistent with the result of REBA: shoulders and hips had the highest average specific REBA scores from all farming activities measured.

5 Recommendations

Given the alarming fact that most of the activities in the farm have high to very high-risk REBA scores indicating an urgent need to improve these activities, specific recommendations for each activity were created to reduce the risk of acquiring WMSDs from that activity. These recommendations can be divided into two: manual and machine methods.

The researchers recognise the invaluable advantages that using machinery brings, especially on the strain it saves the farmers, but recommend mechanising with caution. Many Filipino families depend on farming as their primary, if not only, source of income and subsistence. To unequivocally recommend mechanisation would mean displacing hundreds of thousands of families of their income, an implication too grave and severe to be ignored. In light of this, recommendations did not include mechanisation of an activity.

Manual

Seedbed Preparation, Hauling

For seedbed preparation and hauling which require picking up and carrying heavy loads, it is recommended that they bring a wheelbarrow along to place the, respectively, seedlings and cut rice stalks in. This will greatly reduce the stress on the arms from not having to carry the heavy weight of the seedlings or the rice stalks and eliminate the need to keep bending to pick up fallen seedlings or cut rice stalks. In picking up these loads, the farmers should use their legs to lift and not their backs They should also keep the load close to the body to lessen the strain on their backs and arms.

Aside from wheelbarrows, plastic containers placed and moved via a hand truck could be used as well. The wide containers should be standardized to allow each to be stacked on top of the other, allowing the transfer of more seedbeds per trip. The hand trucks, just like the wheelbarrows, would eliminate the need to carry the heavy loads as all the farmer would need to do is push the hand truck with the containers to move and transport them.

Reaping

In reaping, a sickle (locally known in San Miguel as "*lingkaw*"), a hand knife with a curved blade, is used to cut the rice stalks. From observation, the researchers noticed that the sickles used by the farmers were not standardised and differed in various aspects such as grip handle diameter, length, angle, curvature, and even thickness of blade. Mixing these would force farmers to apply a different posture every time in adjustment to the new sickle. At times, however, this adjustment compromises the farmer: take for example if a shorter-handled sickle is given to a tall farmer, he would be forced to bend lower than usual.

Standardised sizes should be used instead to decrease adjustment to stabilise the reaping procedure. Different standard sizes can be created, such as standardised small and large, to accommodate the variations in farmer height. In determining the proper length of the sickle, the farmer's height relative to that of the rice stalks must be considered so that the farmer would not be forced to bend down every time they cut. The curvature of the sickle must also be optimised to minimise bending and snapping of the wrist, all while ensuring the safety of the farmer in that it is not so curved that a farmer accidentally exerting too much effort in reaping would end up piercing himself.

Machine

Plowing

The use of the rotovator for plowing has become widespread in the farming industry but still poses ergonomic risks. The fixed steering wheel of the machine, positioned at an awkward angle, forces the farmer to bend forward and twist their body to maneuver the machine. Levers too far placed force farmers to overstretch their arms to reach them whereas the inadequate leg space requires farmers to cramp their legs in order to fit.

To address these concerns, the machines should be tailored to the anthropometric measurements of Filipinos or at least include adjustable settings (e.g. adjustable steering wheel distance, incline, height) to make up for these anthropometric differences. This would reduce excessive bending, twisting, and stretching. Another consideration would be to add a steering wheel knob, commonly used by taxi drivers, to lessen the effort needed to turn the wheel, thus reducing the need to bend and twist the body when maneuvering the vehicle as well.

Harrowing and Levelling
Harrowing and levelling via hand tractor subject the farmer to *very* unstable postures which are *especially* compromising to the back. The inadequate support provided by the machine forces the farmer to really stoop forward to support himself. To solve this problem, properly-levelled seats, as well as adequate supports, should be integrated into the machine. A backrest should be added as well for the farmer to lean and rest on since this step takes a long time to complete.

Because of the tractor's short handles, the farmer has to generate enough force to turn the tractor by bending sideways and pushing on the handle, exerting all his weight, with a full-body force. Not only is this extremely dangerous but it is harmful to the body. Incorporating long handles into the tractor would lessen the force and effort needed to turn the vehicle, thus making it safer for the farmer.

All Activities
For all activities, however, job rotation and altering the working position are recommended to avoid staying in an awkward posture for too long. This is *especially* recommended for planting, which subjects the farmers to repetitive motions at an extremely bad posture. Taking regular rest breaks is strongly recommended as well, especially for the Philippine culture wherein there is an innate trait of being resilient (*"matiisin"*) in that Filipino farmers will keep working and will simply bear and/or ignore whatever pain they may be experiencing to finish their jobs.

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References

1. FAO Regional Rice Initiative. Fao.org (2017). http://www.fao.org/fileadmin/templates/agphome/scpi/Document_pdfs_and_images/Presentation_RRI-Philippines.pdf. Accessed 02 Dec 2017
2. Review of Occupational Injury and Related Injuries in the Philippines. International Council on Alcohol, Drugs, and Traffic Safety (ICADTS International) (2017)

3. E. Education, E. Software, C. Center and F. Consultation, “The Definition and Causes of Musculoskeletal Disorders”, Ergonomics Plus (2017). http://ergo-plus.com/musculoskeletal-disorders-msd/. Accessed 02 Dec 2017
4. CDC - Ergonomics and Musculoskeletal Disorders - NIOSH Workplace Safety and Health Topic. Cdc.gov (2017). https://www.cdc.gov/niosh/topics/ergonomics/default.html. Accessed 02 Dec 2017
5. Uy, D.: World Bank sees Philippine rice output rising 2%. Business World (2017)
6. Inquirer: Philippine farmers among least mechanized in Southeast Asia (2017)
7. Filipino farmers - a dying breed? IRIN (2017). http://www.irinnews.org/feature/2013/02/26/filipino-farmers-dying-breed. Accessed 02 Dec 2017
8. Ageing and work-related musculoskeletal disorders. Health and Safety Executive, p. 1 (2017)
9. Inquirer: PSA: poorest of the poor still the same (2017)
10. Gheno, R., Cepparo, J., Rosca, C., Cotten, A.: Musculoskeletal Disorders in the Elderly, Musculoskeletal Disorders in the Elderly (2017). https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3424705/#ref3. Accessed 02 Dec 2017
11. Kolstrup, C.: Work-related musculoskeletal discomfort of dairy farmers and employed workers. J. Occup. Med. Toxicol. **7**(1), 23 (2012)
12. Thetkathuek, A., Meepradit, P., Sa-ngiamsak, T.: A cross-sectional study of musculoskeletal symptoms and risk factors in cambodian fruit farm workers in Eastern Region, Thailand, Safety and Health at Work (2017)
13. Rogan, A., O’Neill, D.: Ergonomics aspects of crop production in tropical developing countries: a literature review. Appl. Ergon. **24**(6), 371–386 (1993)
14. Hignett, S., McAtamney, L.: Rapid entire body assessment (REBA). Appl. Ergon. **31**(2), 201–205 (2000)
15. Kuorinka, I., Jonsson, B., Kilbom, A., Vinterberg, H., Biering-Sørensen, F., Andersson, G., Jørgensen, K.: Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. Appl. Ergon. **18**(3), 233–237 (1987)
16. Ahmadi, A., Mirzayee, R., Ansari, H.: Assessment of work postures and prevalence of musculoskeletal disorders among porcelain industry workers. J. Occup. Health Epidemiol. **4**(3), 146–153 (2015)
17. Statistical Correlation, Explorable.com (2017). https://explorable.com/statistical-correlation. Accessed 02 Dec 2017

Social and Occupational Ergonomics of Stress, Mental Factors and Musculoskeletal Disorders

Addressing Mental Health Consequences of Social Networking from the Social Services Perspective

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Abstract. Recently, scientists started to investigate the potential negative effects of Social Networking sites (SNs). In addition to their positive contribution to our lives, several studies demonstrated correlation between prolonged use of SNs and the occurrence of mental health conditions, such as, anxiety and depression. Their pervasive presence in individuals' lives and their psychological and social dynamics might affect people who are especially vulnerable. In this paper, we introduce an assessment tool designed for evaluating the impact of social media usage on individuals with mental health conditions, with a specific regard to teenagers. The tool, which was co-designed with therapists, consists of a short questionnaire that can be utilized to identify the presence of social media-related risks on mental health, and their severity.

Keywords: Social media · Assessment · Mental health · Baker Act

1 Introduction

The growth, power, and value of social networks have no predecessors in any other type of media: nowadays, they help billions of individuals connect, share, inform, and influence. Although there are clear advantages in social media [1], recent research studies started investigating the emotional downsides of social networking systems and their impact on people's mental health [2–5], especially in regard to diverse populations [6]. This is especially relevant for teenagers, who inherently are a population at risk: According to statistics from 2015 [7], suicide is among leading causes of death for individuals between the ages of 10–24, in the United States and in other developed countries. Moreover, a report from the U.S. Centers for Disease Control and Prevention [8] showed that the suicide rate for teenage girls doubled from 2007, and in 2015 it reached its highest point in the last 40 years [7]. This trend reflects statistics of cyberbullying in social networking: a study about cruel behavior on social media revealed a shift from 27 to 87% in one year, only [1].

Indeed, social media has several advantages in enhancing the way people communicate, which in turn, has a positive impact on individuals' lives [9–11]. The authors of [1] show that one in three youth feel more accepted on social networks than they do in real life, which might be an argument in support of social media; nevertheless, it demonstrates

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its power in influencing emotions, feelings, and behavior. In addition, smartphones contribute to radically changing every aspect of teenagers' lives, from lifestyle to the nature of their social interactions: the more they are drawn to social media via their smartphones, the more likely they may be to stay indoors and avoid physical activity. Consequently, nowadays individuals are safer than they have ever been from corporal damage standpoint; however, their mental health might be at risk [12].

Although there is no direct proven connection between social media and self-harm, cyberbullying, cyber harassment, being threatened, humiliated and embarrassed on social networking sites increase the risk of pro-suicide behavior [13]. Also, research revealed correlation between social media use and mental health conditions, such as symptoms of inattention, hyperactivity/impulsivity, ODD, anxiety, fear of missing out [5] and depression [2–4], with stronger effects associated with number of accounts on social media sites and longer time spent on the Internet [5]. Teenagers and middle- or high-school students are especially at risk, as demonstrated by [14], which explored dynamics, such as, unmet need for support, self-rated mental health, and reports of psychological distress and suicidal ideation. Specifically, the expression "Facebook depression" has been devised to represent a condition which teenagers and young adults spend too much time using social media sites [15]. This, in turn, is extremely relevant to self-harm, because the Center for Disease Control and Prevention (2016) reports that 90% of people who commit suicide have a mental health illness at the time of their death, with depression being the top risk factor [16, 17].

Moreover, recent reports showed three-fold increase in cyberbullying on social networking sites [18], and several studies linked digital harassment and violence (e.g., sexting) with suicide attempts [19, 20]. As a result, it is imperative that social services, parents, caregivers, and friends increase their awareness on how social media might affect mental health in individuals who are at risk. Unfortunately, topics regarding mental health are still stigmatized. Consequently, when people who suffer from a mental health diagnosis experience hate or violence to some extent on social media sites, they continue to use the Internet to escape the outside world, and alienation increases the risk for their mental health of being impacted by what they see and read.

Indeed, social services have always played a crucial role in implementing initiatives to address harmful behavior that can lead to suicide and prevent it from happening. Specifically, the State of Florida issued the Baker Act [21], a voluntary or involuntary examination of a person who is believed to have a mental health illness, or who shares that they have the intent to kill or harm themselves or someone else. However, according to therapists, currently there are no tools for measuring the causes of Baker Acts, in correlation to social media.

In this paper, we introduce an easy-to-use assessment tool that can be utilized to determine the impact of social media on vulnerable people. Our questionnaire was co-designed with therapists to help identify the presence, type, and severity of negative effects related to social networking, and to support defining countermeasures that can be implemented to prevent potentially harmful consequences. By understanding and addressing the dynamics behind these figures, health providers and families could offer dedicated support for teenagers and people who are most vulnerable to the downsides of social networking and refer them to expert therapists.

2 Related Work

In the state of Florida there are 105 Florida Department of Children and Families that are designated as Baker Act receiving facilities [22]. The Florida Baker Act law allows for emergency commitment if there is evidence of a) mental illness and b) harm to self, harm to others, and/or self-neglect [22]. There are three groups of individuals that can initiate emergency commitment and those are judges, mental health professional and law enforcement personnel. Baker Act receiving facilities have a process that is followed to complete a risk assessment, the tools they use may be different, but they all share the same goal and that is to measure the risk of the individual being committed. Some of the tools that may be incorporated into the comprehensive assessment are the Beck Depression Inventory, Suicide Ideation Survey, Scale for Suicide Ideation, Suicide Intent Scale, Beck Hopeless Scale and the Linehan Reasons for Living Inventory.

A study by the University of South Florida investigated the type of assessments completed at Baker Act facilities and found that the most commonly used assessments methods are the Beck Depression Inventory, Suicide Ideation Survey and Adult Suicide Ideation Survey [22]. They are primarily employed at Baker Act receiving facilities as an initial screening. The Beck's Depression Inventory Scale includes 21 questions and the participant can answer on a Likert scale from 0 to 3; at the end of the survey, depending on their score, subjects are able to identify how depress they are. As the tool was designed several years ago, its questions do not include social media use as a factor, though it is currently reported among the causes of depression in teenagers [2–5]. According to National Action Alliance [23], the Suicide Ideation Survey (SIQ) was designed for school-aged youth to assess their risk of committing suicide. The questionnaire consists of four parts focusing on: likelihood of suicide, frequency of suicidal ideation over the last year, lifetime suicide ideations/attempts, and threat of suicide attempt. Like the Beck's Depression Inventory Scale, this questionnaire does not identify whether social media use is a trigger to suicide attempt or ideation. In comparison to the Suicide Ideation Survey, which is employed with school-aged youth, the Adult Suicide Ideation Questionnaire is similar, in the sense that it is used to assess the acuity and severity of suicidal ideations, without addressing their causes [24]. As a result, none of the top three tools administered at Baker Act receiving facilities assess whether social media use is a trigger and may have a correlation to self-harm and suicide attempt. Although there might be facilities that implement practices that address cyberbullying and other social media-related factors, their use is not reported in the literature or shared among multiple organizations operating under the Baker Act.

The authors of [25] designed a cyberbullying inventory tool (CBI/RCBI) to investigate the nature and extent of an experience involving exposure to cyberbullying dynamics. The CBI/RCBI tool consists of two items: (1) the cyberbullying form and (2) the victimization form. Each form includes 34 questions, which asks partakers to rate their experience on a four-point Likert scale. Typically, a short questionnaire would be administered to youth in the age of 14–18 to understand their social media usage; then, based on the pre-test scores, they would be asked to participate in a focus group in which the CBI/RCBI would be provided. Although this tool may be helpful in investigating the extent of cyberbullying, it does not measure the probability of someone attempting or completing suicide due to being cyberbullied, or other forms of harm which result from using social networking, because the CBI/RCBI focuses on understanding the causes, rather than addressing the potential consequences and their severity. Also, this tool is not employed in Baker Act facilities.

Currently, the physical facility and the suicide hotline are the first points of contact for someone who has self-harm ideations, if they are open to help. The assessor addresses their mental health state by using a tool to measure the risks of attempting or completing suicide. A different system could be utilized depending on the facility and on the intervention unit. For instance, the Crisis Center of Tampa Bay utilizes the iCarol suicide assessment tool. Regardless of the instrument, the goal of the assessor is three-fold: (1) identify the level of risk of suicide, (2) attempt to deter the situation, and (3) define a safety-plan for the caller, which may involve completing additional steps (e.g., visiting the physical facility or receiving a visit from the mental health services). If realized over the phone, the assessment mainly consists in asking the caller the following questions: (1) are you thinking of suicide? (2) have you thought about suicide in the last two months? (3) have you ever attempted to kill yourself? (4) have you ever been hospitalized for MH/Suicide? (5) is suicide in progress? The risk of self-injury is rated at the beginning of the call, so that the goal of the assessor before the call ends is to decrease the level of suicide risk. To this end, the assessment involves discussing and documenting reasons for dying and living. Therefore, the assessor must consider several factors, including the identifying the individual's motivation for suicide initiation, while having a conversation with the caller.

As a result, to our knowledge, there are no questionnaires that enable the Crisis Center of Tampa Bay to explore the likelihood of social media being a factor or trigger in their suicidal ideations, or they are not being utilized due to several different reasons. For instance, current inventories, such as, the CBI/RCBI, consist of multiple items and they are not suitable for providing the assessor with quick feedback to determine whether social media could be a risk factor or trigger to self-harm and/or suicide attempt.

3 Assessment Tool Design

In this paper, we introduce the Social Media Mental Health Risk Assessment (SMRA) tool (Fig. 1), which provides assessors, therapists, and other professionals in mental health services, with a system for achieving a quick evaluation of whether social media plays a role in individuals' mental health conditions. The tool is designed to serve as a supplement to the assessment methods already being utilized at Baker Act facilities and in similar organizations. Typically, the SMRA instrument would be administered when subjects complete a bio-psychosocial assessment and when their traumatic history is explored. In this context, the tool can be integrated in the assessment procedure to explore social media triggers that are not currently addressed. The goal of this tool is to assist therapist in identifying the presence, nature, and severity of social media-related risk in subjects. Specifically, the SMRA tool is designed provide insights on whether social media affects the individual and the extent to which it triggered them. Although it is especially created to assess the risk of using social media in youth/young adults who are referred as having mental health conditions, the tool can be utilized with any type of population, to identify potential negative effects related to the use of social network sites.

To this end, we reviewed available risk assessment methods and tools focusing on social media, and we analyzed their pros and cons with mental health professionals. Moreover, we conducted several interviews with therapists and we organized meetings with them to co-design the elements of the questionnaire with their help. Their support contributed to achieve an understanding of (1) the context of use, (2) the risk evaluation procedure and the protocols that can be implemented depending on the output of the assessment phase, and (3) the different aspects of risk that serve as indicators for further treatment. As a result, we aimed at designing a short inventory that can be utilized by an assessor during a call to guide their conversation and to identify strategies for preventing harm. Also, the questionnaire consists of five modular elements each addressing a specific dimension of risk (discussed in Sect. 4). The SMRA tool can be integrated with other methods and it can be utilized as an additional layer to achieve a more complete overview of an individual's mental health situation. Moreover, questions were organized into versatile items that can be modified by professionals and organizations to better represent the specific situations they are dealing with. Finally, the instrument is conceived to support Plan-Do-Check-Adjust (PCDA) protocols, and it can be utilized to elicit further intervention from therapists, family members and other stakeholders in mental health and in the community.

Several iterations of the tool were produced and evaluated by experts in the working group. Subsequently, the final version of the tool was sent to three licensed mental health therapists who provided additional feedback about the applicability of the SMRA tool to actual contexts and gave additional suggestions on how to improve the design of the questions.

The first therapist who reviewed the tool has one and a half year of experience in administering assessment at a Baker Act facility: they judged the instrument as appropriate, showed interest in integrating it in the process and provided availability for the validation phase. The second expert who reviewed the tool is a licensed clinical social worker who currently works in the mental health field; they especially appreciated the brevity of the tool and they indicated that the SMRA tool can be utilized effectively as a risk-specific interview checklist, in combination with other assessments required by Baker Act facilities. The third reviewer who commented on the tool is a licensed mental health counselor with over 35 years of experience in the mental health field: they proposed improvements to the design of the scale and gave positive feedback regarding its usefulness.

1) Your relationship with social media:

A) How many social media accounts do you have?	
B) How many hours per day do you spend on social media?	

2) Social media sites are a source of:

Use scale 1- 10 below: 1 being extremely comfortable and 10 being extremely stressful.

Comfort									Stress
1	2	3	4	5	6	7	8	9	10

For each of the questions below, circle the response that best characterizes how you feel about the statement, where: 1= Strongly Disagree, 2 = Disagree, 3 = Neither Agree nor Disagree, 4 = Agree and 5 = Strongly Agree

3) As a result of using social media sites:

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
What others post negatively affects my mood	1	2	3	4	5
I look for affirmation or acceptance from others	1	2	3	4	5
I feel sad when people ignore my posts	1	2	3	4	5
I am teased, attacked, or threatened	1	2	3	4	5
I feel fearful or anxious	1	2	3	4	5
I feel sad or depressed	1	2	3	4	5
I feel the urge to hurt myself	1	2	3	4	5

4) How often do you experience the following while using social media:

	Never	Very rarely	Occa-sionally	Frequently	Very frequently
Getting directly engaged in arguments	1	2	3	4	5
Being ignored or excluded	1	2	3	4	5
Hate or people insulting you	1	2	3	4	5
Denigration via gossip or rumors about you	1	2	3	4	5
Cyberbullying	1	2	3	4	5
People embarrassing you with graphic material	1	2	3	4	5
Harassment	1	2	3	4	5
Online/Cyberstalking	1	2	3	4	5

5) If you have had any of these experiences:

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I have been able to resolve them	1	2	3	4	5
I have received help about them	1	2	3	4	5
I am still experiencing them	1	2	3	4	5
I solved them, but they still have an impact on my feelings	1	2	3	4	5
I don't think I will be able to solve them	1	2	3	4	5

Fig. 1. The social media mental health risk assessment (SMRA) tool.

4 Risk Assessment and Treatment

In this Section, we describe the main components of the questionnaire in terms of analysis of the risk factors associated with the questions. The SMRA tool contains 5 sections and a total of 23 items that can be utilized to evaluate risk over five dimensions include: occurrence, outcome, severity, cause, and status. Each risk dimension is utilized to address a specific aspect and contributes to formulating a risk profile for the individual. To this end, the total risk score r associated with social media use can be calculated as the sum of the specific risk factors (questions 2 to 4), multiplied by the number of hours spent on social media (question 1B), that is, $r = h * (r_{outcome} + (3 * r_{severity}) + (2 * r_{cause}) + r_{status})$. The formula takes into consideration the increasing gravity of the items listed in the questionnaire and the different weight (in terms of impact on mental health) of the topics discussed in the questions. Moreover, risk dimensions can be analyzed individually using the formulas described below.

4.1 Occurrence

The first question investigates the individual's relationship with social media, i.e., the number of accounts that they have, and the amount of time spent on SNs. The first part of question 1 enables the therapist to gage how many accounts the client has, if none; the supplemental tool does not need to be used. The latter element of the question is expressed in hours per day and it results in the h of the formula for calculating r. This originates from [14], which found a correlation between social media consumption time and mental health conditions. If the person being interviewed with the tool presented in this paper indicates that they spend several hours a day on social media, this should flag the therapist in relation to the risk associated with other dimensions. Even if the total risk factor resulting from the formula is low, responses indicating more than two hours a day should suggest the therapist to address how subjects spend their time online.

4.2 Outcome

The second question of the tool design allows the interviewee to rate whether social media sites are source of comfort or stress on a scale of 1–10. This is the perceived outcome $r_{outcome}$ of social media use, which considers the potential positive effect of social media on subjects. The higher the score that is indicated, the more likely the individual would benefit from speaking to a therapist regarding their stress level on social media.

4.3 Severity

Question 3 regards the severity of risk, which is directly associated with the type of harm that the client might inflict. The associated risk can be calculated as $r_{severity} = \sum_{i=0}^{7} i * q_i$. The therapist should give great concern to this area, as it indicates the direction that the subject might take because of an inappropriate use of social media or as a result of social media-related risk. A higher score indicates that social media is a cause of distress and the client might have suicidal ideations. Consequently, a safety-plan should be discussed. A lower score indicates that social media is not affecting the client's mood and there is limited physical risk or psychological risk. If the subject results in moderate score, then their risk is low to social media, however this should be addressed as the risk may increase with more frequent use of social media.

4.4 Cause

Question 4 focuses on the type of traumatic experience and the impact it may have on the individual, which can be utilized to initiate a root cause analysis of the problem and to suggest specific intervention measures. The associated risk can be calculated as $r_{cause} = \sum_{i=0}^{8} i * q_i$. It addresses a three-fold component: (1) whether the individual is a victim of cyberbullying, (2) the type of behavior experienced by the subject, and (3) the extent of the phenomenon. Based on the frequency that the individual indicates, the therapist can focus on this topic during therapy and provide specific resources on what to do when being bullied. The maximum score in this section is 40; however, even if a client has high scores on some of the items in this section, then they should not be released from Baker Act until a safety-plan is provided and discussed. If client is under 18, parents should be notified, and they should be part of their safety plan. Otherwise, the therapist should plan to incorporate cyberbullying risk in their treatment and provide suggestions on how to cope with emotions brought from others on social media sites.

4.5 Status

In question 5, the tool focuses on the status of the current problem, and it helps the therapist understand whether their client has had treatment or has spoken to anyone regarding their experience on social media. The associated risk can be calculated as $r_{status} = \sum_{i=0}^{5} i * q_i$. A high score on item 1 ("I have been able to resolve them") might result in initiating an insightful conversation about the issue that the individual experienced and solved in the past, whereas items 2 and 3 might require further investigation and support. If the tools suggest that the interviewee has not addressed any of the problems, then appropriate level of intervention should be suggested. To this end, therapy or natural supports (e.g., family members) should be incorporated into the treatment plan, because being able to speak to someone about these issues may decrease the risk of suicidal ideations. Also, item 5 ("I don't think I will be able to solve them") should require appropriate intervention, as it reveals individuals' discouragement in dealing with the issue. Furthermore, even if it is determined that no one has addressed any of the questions discussed in the tools, then prior to discharge from the Baker Act, the therapist assigned should provide resources, come up with a plausible solution and encourage natural support involvement to lower the risk of social media use in regard to mental health.

5 Conclusion and Future Work

In this paper, we introduced a Social Media Mental Health Risk Assessment (SMRA) tool and we documented its motivation and design. The SMRA tool consists of 5 questions and it constitutes a brief and easy-to-use inventory that is designed to evaluate the presence of social media-related risk for mental health. The questionnaire can be administered to a variety of populations, including people who are especially vulnerable, such as, teenagers, young adults, and individuals who are referred to or contact mental health service providers.

The tool takes into consideration several risk factors, such as, the probability of occurrence, the type of relationship with social media, the psychological component of risk, the potential cause of damage and the severity of the situation. Each factor is addressed by a specific question (and by its sub-items), which would improve the efficiency in administering the SMRA tool over the phone or during assessment interviews. Indeed, the instrument is designed to be integrated in a more comprehensive process: combined with established methods, it can be utilized as an initial screening to identify additional types of support and to implement risk assessment protocols that consider the specific type of risk.

The purpose of this paper was to introduce the tool and to share the work realized with therapists with the scientific community working on mental health, to receive feedback from therapists and experts and to foster the debate about the consequences of social media on mental health and their potential risks in different types of populations. In a future study, we will realize an observational study in which the tool will be administered by therapists to a small group of volunteers. The ultimate goal of this work is to promote the adoption of the SMRA tool in mental health services. In addition to supporting therapists, the tool can have a crucial role in increasing awareness on social media-related risks which, as reported by the literature, is an underestimated component in mental conditions.

References

1. Teens and the Screen study: Exploring Online Privacy, Social Networking and Cyberbullying, McAfee, 3 June 2014. https://www.mcafee.com/us/about/news/2014/q2/20140603-01.aspx
2. Lin, L.Y., Sidani, J.E., Shensa, A., et al.: Association between social media use and depression among U.S. young adults. Depress. Anxiety **33**(4), 323–331 (2016). pmid:26783723
3. Lup, K., Trub, L., Rosenthal, L.: Instagram #instasad?: exploring associations among instagram use, depressive symptoms, negative social comparison, and strangers followed. Cyberpsychol. Behav. Soc. Netw. **18**(5), 247–252 (2015). pmid:25965859
4. Levenson, J.C., Shensa, A., Sidani, J.E., Colditz, J.B., Primack, B.A.: The association between social media use and sleep disturbance among young adults. Prev. Med. **85**, 36–41 (2016). pmid:26791323
5. Barry, C.T., Sidoti, C.L., Briggs, S.M., Reiter, S.R., Lindsey, R.A.: Adolescent social media use and mental health from adolescent and parent perspectives. J. Adolesc. **61**, 1–11 (2017)
6. Stanton, A.: An Investigation of How Social Media Use Impacts Strong Black Woman Embodiment and Mental Health (Doctoral dissertation) (2016)
7. Sullivan, E.M., Annest, J.L., Simon, T.R., Luo, F., Dahlberg, L.L.: Centers for disease control and prevention (CDC). Suicide trends among persons aged 10–24 years–United States, 1994–2012. MMWR Morb. Mortal. Wkly Rep. **64**(8), 201–205 (2015). pmid:25742379
8. Mercado, M.C., Holland, K., Leemis, R.W., Stone, D.M., Wang, J.: Trends in emergency department visits for nonfatal self-inflicted injuries among youth aged 10 to 24 years in the United States, 2001–2015. JAMA **318**(19), 1931–1933 (2017). https://doi.org/10.1001/jama.2017.13317

9. Naslund, J.A., Aschbrenner, K.A., Marsch, L.A., Bartels, S.J.: The future of mental health care: peer-to-peer support and social media. Epidemiol. Psychiatr. Sci. **25**(2), 113–122 (2016)
10. Naslund, J.A., Grande, S.W., Aschbrenner, K.A., Elwyn, G.: Naturally occurring peer support through social media: the experiences of individuals with severe mental illness using YouTube. PLoS ONE **9**(10), e110171 (2014)
11. Fergie, G., Hunt, K., Hilton, S.: Social media as a space for support: young adults' perspectives on producing and consuming user-generated content about diabetes and mental health. Soc. Sci. Med. **170**, 46–54 (2016)
12. Twenge, J.M.: Have smartphones destroyed a generation. The Atlantic (2017)
13. Robinson, J., Cox, G., Bailey, E., Hetrick, S., Rodrigues, M., Fisher, S., Herrman, H.: Social media and suicide prevention: a systematic review. Early Interv. Psychiatry **10**(2), 103–121 (2016)
14. Sampasa-Kanyinga, H., Lewis, R.F.: Frequent use of social networking sites is associated with poor psychological functioning among children and adolescents. Cyberpsychol. Behav. Soc. Networking **18**(7), 380–385 (2015)
15. O'Keeffe, G.S., Clarke-Pearson, K.: Council on communications and media. clinical report: the impact of social media on children, adolescents, and families. Pediatrics **127**(4), 800–804 (2011). pmid:21444588
16. American Foundation for Suicide Prevention. Suicide Statistics (2016). <https://afsp.org/about-suicide/suicide-statistics/>
17. Center for Disease Control and Suicide Prevention. Suicide and Self-Inflected Injury (2016). https://www.cdc.gov/nchs/fastats/suicide.htm
18. Mishna, F., Regehr, C., Lacombe-Duncan, A., Daciuk, J., Fearing, G., Van Wert, M.: Social media, cyber-aggression and student mental health on a university campus. J. Ment. Health 1–8 (2018)
19. Junco, R.: Resharing of Images or Videos Without Consent: A Form of Relationship Violence and Harassment. Harmful Speech Online 16 (2017)
20. Medrano, J.L.J., Lopez Rosales, F., Gámez-Guadix, M.: Assessing the links of sexting, cybervictimization, depression, and suicidal ideation among university students. Archives of Suicide Research, 1–12 (2017)
21. Department of Mental Health Law & Policy. Baker Act: The Florida Mental Health Act (2014). http://www.dcf.state.fl.us/programs/samh/mentalhealth/laws/BakerActManual.pdf
22. Roggenbaum, S., Christy, A., LeBlanc, A.: Suicide assessment and prevention during and after emergency commitment. Commun. Ment. Health J. **48**(6), 741–745 (2012)
23. National Action Alliance for Suicide Prevention: Youth in Contact with the Juvenile Justice System Task Force. Screening and assessment for suicide prevention: Tools and procedures for risk identification among juvenile justice youth. Washington, DC (2013)
24. Reynolds, W.M.: Psychometric characteristics of the adult suicidal ideation questionnaire in college students. J. Pers. Assess. **56**(2), 289–307 (1991)
25. Topcu, Ç., Erdur-Baker, Ö.: The revised cyber bullying inventory (RCBI): validity and reliability studies. Procedia-Soc. Behav. Sci. **5**, 660–664 (2010)

Ergonomic Analysis of the Operators' Activity in an Industrial Agri-Food Workshop

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Abstract. The current intervention was carried out in a leading company in the agri-food sector in Tunisia. The initial request was the reduction of absenteeism related to musculoskeletal disorders.

Methods: We proceed to an ergonomic intervention based on two phases. The first one focused on understanding the company global functioning. The second phase focused on the analysis of the activity of operators of the cutting workshop and involved systemic observations and interviews with the operators of this workshop.

Results: The intervention among the cutting workshop operators objected that biomechanical constrains (repetitively, poor recovery time and manual strength) organizational and psychosocial factors were significant and variable depending on the transaction carried out.

Conclusion: we identified action plan to improve working conditions and reduce absenteeism. These reflections focused on two areas; the arrangement and the organization of the workshop and the introduction of new equipments and technical solutions.

Keywords: Agri-food sector · Musculoskeletal disorders
Analysis of the activity

1 Introduction

The world of work is experiencing a rapid industrialization that is emerging particular forms of organizations of the work system (assembly-lines, zero stockholding, lean management, …) [1]. In Tunisia, these organizational forms imposed, by globalization, are strengthening the competition between companies. This latter leads to the emergence of multiple work-related pathologies such as musculoskeletal disorders (MSDs) [2, 3].

In several industrialized countries, as in Tunisia, MSDs are the first compensated occupational diseases [4]. According to national statistics, several professional sectors are concerned by this scourge such as the clothing industry, manufacturing industries,

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buildings and public works, and the agri-food sector [4]. These sectors are characterized by common risk factors such as repetitiveness, short work cycle time, monotonous task, manual work, strong organizational dependence, and psycho organizational risks [5].

The agri-food sector generates an added national value around 20% [6]. Moreover, in terms of employability, it guarantees fixed and seasonal employment [6]. In this sector, companies employ 73,000 people, that corresponds to 20% of manufacturing jobs. Thus this sector ranks second in terms of employability after the textile and clothing sector [6]. The workforce of this industrial branch, mainly female, is characterized by low qualification.

The company of the current intervention is active in the field of delicatessen and is among the largest in the Tunisian market. This intervention responds to a request to reduce absenteeism related to MSDs in the cutting workshop. This intervention enabled to formulate action, notably concerning the design of new projected work spaces.

2 Materials and Methods

a. Presentation of the Company

This company was created in 1995 as a poultry company. It has developed in 2001 a sector that ensures the slaughter, processing and distribution of poultry. It finally specialized in breeding, slaughter, cutting, packaging and distribution of poultry.

In this company, from slaughterhouse to processing, packaging and storage, everything is done on the same site in a very short time (<24 h). In recent years, the company has focused its production and quality policy on satisfying consumer expectations and the challenges of national poultry markets. The company's products are diversified including both cut chicken, turkey cut, ham, salami, sausage, breaded frozen products, marinated products and eggs.

b. Request for Intervention

The request for this intervention came from the company's safety officer and focused on the absenteeism of workers directly or indirectly related to MSDs.

An analysis of the situation was conducted on the basis of registers and documents of the company concerning absenteeism, the declaration of occupational diseases and accidents at work and those related to turnover and recruitment and records of workers (seniority, age …).

This analysis revealed an increase in absenteeism in the cutting workshop. This was mainly due to absenteeism secondary to MSDs of the back and upper limbs directly (reason displayed on the medical certificate) or indirectly (following the interview at the recovery consultation).

In addition, during a meeting with the safety manager and the production manager, activity and workshops extension projects and the development of the staff (to increase it approximately 20% within two years) have been announced.

The first phase of the project focused on the cutting workshop. This workshop is strategic for the other workshops because it provides the raw material necessary for their production. It is the "conductor of this production". Yet, its operators are more affected by absenteeism. The other workshops and the administration were treated in a second phase. The fear of the managers was that the MSDs become a barrier against the objectives of production and quality set by the company, especially in the cutting workshop.

The negotiation of the request reformulate it around this project of extension. Indeed, the company, as part of its workforce expansion and productivity increase, has planned the construction of a new building dedicated to cutting. The contribution of Ergonomic throughout the design phase of the cutting workshop could reduce the MSDs among the operators concerned.

c. **Course of the Intervention**

This ergonomic intervention was performed in two phases. The first step assured the understanding of the global functioning of the company. The second step focused on the cutting workshop and the activity of its operators.

The first step consisted on open observations and interviews with the operators working in various workstations and workshops.

The second phase involved systemic observations and interviews with operators. It focused on the analysis of the activity of the operators of the cutting workshop.

These different phases enabled to develop an action plan to reduce MSDs in the cutting workshop.

3 Results

The company includes, five workshops located on the same site: slaughterhouse, cutting, cold cuts, freezing and delivery, and the administration (Fig. 1).

The work of these different workshops was highly dependent and orchestrated by the activity of the slaughterhouse workshop and especially the cutting workshop.

The activity in the cutting workshop starts at 7am and ends depending on commands often around 5 pm. Seventy operators (19 men and 51 women) work in this workshop. This sector includes two chains of activity, one dedicated to chicken and the second, longer, dedicated to turkeys (Fig. 2).

After a rest period, poultry arrive from the slaughtering workshop on the suspended mechanical chain. The first step in this workshop is the manual sorting performed by an operator to separate the first choices (the poultry chosen for direct sale) and the second choice (poultry passing through the cutting workshop). The choice of first choice poultry is based on visual aesthetic and size criteria and the absence of damage.

Thereafter three major operations can be provided in this workshop according to the demands: cutting of the different pieces of poultry, deboning of the pulpit and preparation of turkey kebabs (Fig. 3). Poultry carcasses recovered at the end of cutting are crushed to have two types of mixtures. These various operations are carried out by female operators at the chain.

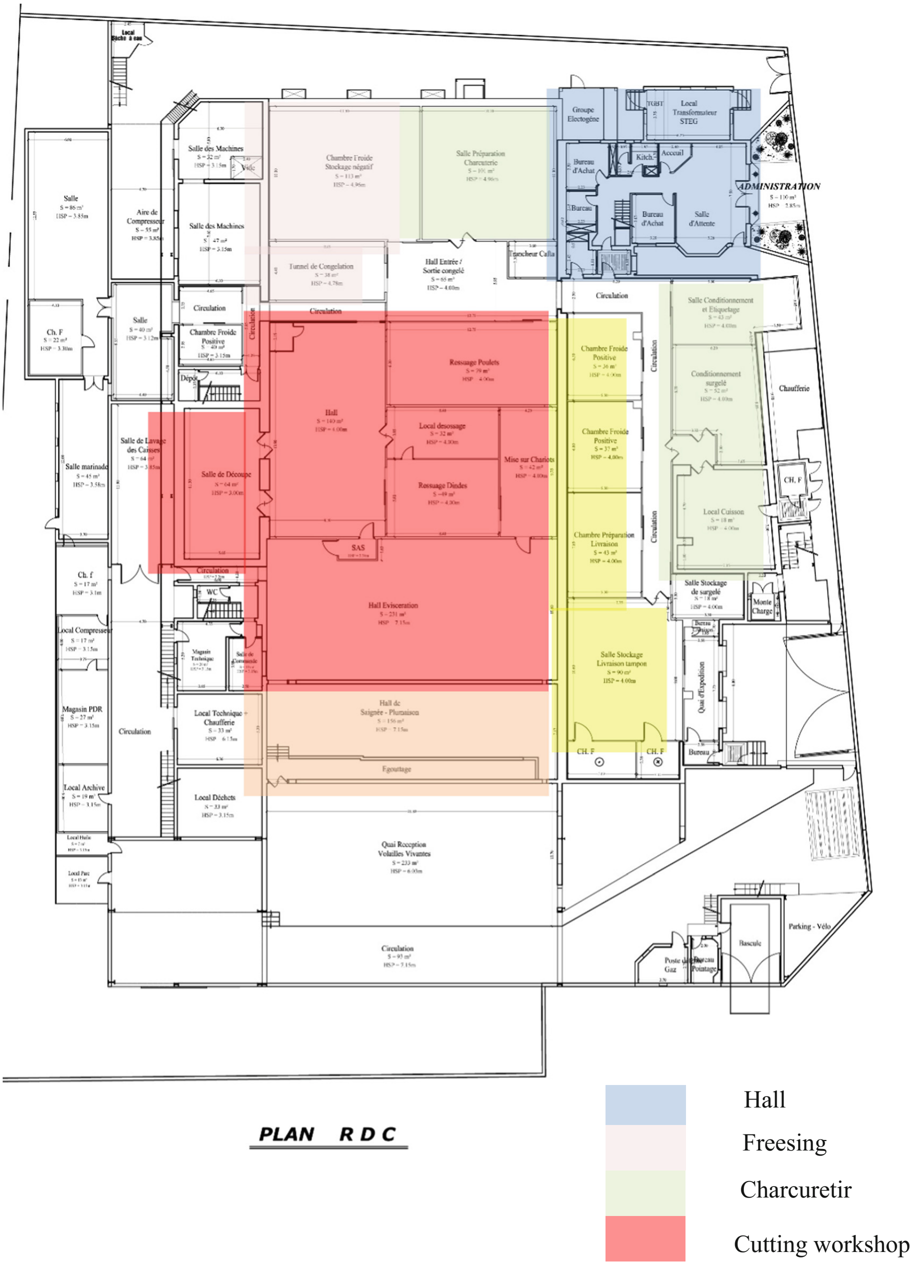

Fig. 1. Plan of the company

Fig. 2. The turkey cutting chain

Fig. 3. The boning chickens sub-zone

a. **Analysis of the Activity of Operators of the Cutting Workshop**

The cutting workshop is spread over an area of 550 m^2 with about 70 operators distributed in the different sub-areas. It is organized around two chains: chicken and turkey.

The cutting workshop occupies an important place in the activity of the company. After a rest of three to four hours, it receives slaughtered poultry. Then this latter goes through a visual sorting to distinguish the poultry.

A dozen of operators (four men and eight women) works in to the turkey cutting chain, the largest chain of the workshop. Two men, placed at the beginning of the chain, transport turkeys to cut them in metal trolleys. The operators of this chain are positioned in front of a metal support on which the poultry are fixed. This support moves thanks to a carpet system with a rhythmicity imposed by the machine.

Each operator has a definite task; the first and the second remove the wings, the third and fourth remove the legs and the last two tend the breasts. At the end of the chain, the turkey carcasses are put in a large container. Then, two operators moves these carcasses to another sub-area for crush to get two types of dough used in the charcuterie workshop. Two other operators sort the parts of turkeys in the trolleys before moving them.

In the second subzone dedicated to turkey boning, additional constraints were observed. In this room, cluttered and badly ordered (crates placed in the middle of the room), the operators worked facing the wall. The professional gesture in this area requires repetitive gestures (>10 movements/min).

During the interviews of the operators of the cutting workshop, a thermal discomfort was a recurring complaint despite the wearing of personal protective equipment type combinations of scarves, boots and orthopedic hooves. This complaint was caused by a very low temperature approaching 0°C and the humid atmosphere. This complaint, according to the operators, was aggravating their complaints of back and upper limb MSDs especially at the wrists and shoulders. The operators also reported that the cutting tools mainly knives were incorrectly mounted which requires additional effort to accomplish the professional task. In addition, feelings of under-valuation, suffocation and imprisonment were reported by operators in the second sub-area.

b. **Reflections and Ways of Transforming Work**

Our intervention among the cutting workshop operators noted that the constraints experienced by the operators of this zone were considerable and variable according to the operation carried out. This analysis showed that repeatability, poor recovery time and manual strength are common to all workstations.

On the basis of these results, we have been able to identify action aimed to improve working conditions, reduce MSDs and related absenteeism. These reflections focused on two axes; the arrangement of the workshop and the equipment and technical solutions. Thus the ergonomic design based on the extension project of the workshop has emerged as an ideal solution to prevent MSDs. In fact, the design of a more suitable work space that meets both the physical requirements and the effort required by the task has been proposed. In addition, quick and simple actions in the current workshop have been advocated such as:

- Moving the work tables to the center of the room in the deboning room provides comfort to the operators and offers an eye contact.
- set up a running carpet at the entrance of the poultry until its delivery to reduce cumbersome.
- In the cutting workshop, use horizontal supports to reduce the feeling of heavy shoulders.
- For the turkey cutting chain a suspended chain can be integrated directly into the slaughter to reduce the passage of trolleys between the operators and to avoid work accidents. This solution could also alleviate the workload for the two operators who transport cut turkeys on metal trolleys, remove the turkeys and depose it on the carpet.

In addition, the introduction of a rotation of workstations for operators, the creation of dynamic micro-breaks and the provision of hot drinks were proposed.

4 Discussion and Conclusion

The initial request for this ergonomic intervention came from the safety officer. This request initially focused on reducing absenteeism. After analysis of the work situation, the reformulated request focused on an arrangement of the cutting workshop to prevent MSDs, a major cause of absenteeism in this workshop. We conducted an intervention with the operators of the cutting workshop. The first part of the intervention was based on open observations and exploratory interviews. This latter was devoted to the comprehension of the global functioning and interactions in various workshops. The second stage was invested on an analysis of the activity of the operators of the cutting workshop to understand the postural and gestural constraints, the performance issues, but also the psycho-organizational constraints.

From all the data collected, we have formulated reflections and transformation paths acting on the biomechanical constraints (facilitating the transport of products using slides, conveyor belts or ball tables, for example, avoiding level changes between two successive work plans, between two contiguous machines requiring a manual grip, using mobile services to move without carrying products and tools, providing handling aids, …) the organization of work (introduce a rotational system and micro-breaks) and psycho-organizational factors (improve communication, ..).

Finally, it emerges from this work that the design phase presents an opportunity for effective ergonomic intervention.

References

1. Bernard, B.P.: Musculoskeletal Disorders and Workplace Factors: A Critical Review of Epidemiologic Evidence for Work-Related Musculoskeletal Disorders of the Neck, Upper Extremity, and Low Back, 1997
2. Punnett, L., Wegman, D.H.: Work-related musculoskeletal disorders: the epidemiologic evidence and the debate. J. Electromyogr. Kinesiol. (2004)

3. da Costa, B.R., Vieira, E.R.: Risk factors for work-related musculoskeletal disorders: a systematic review of recent longitudinal studies. Am. J. Ind. Med. **53**, 285–323 (2010). https://doi.org/10.1002/ajim.20750
4. Ben Lallahom, L.: les troubles musculo-squelettiques ou pathologiques d'hyper sollicitations en rapport avec les gestes répétitifs professionnels. Revue de Santé et Sécurité au travail **4**, 21–26 (1997)
5. dos Santos Leite, W.K., Colaço, G.A., de Souza, E.L., da Silva, J.M.N., Lucas, R.E.C.: Ergonomic risk for WMSDs in activities of footwear assembly. Ceset J. **22**, 35–43 (2016). 35
6. Cail, F.: Journal of conformity of MSDs. Revue travail et Sécurité **9**, 456–458 (1995)

A Systematic Review of Musculoskeletal Disorders (MSDs) Among Port Workers

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Abstract. Musculoskeletal disorders (MSDs) are common and costly health problems that inflict port workers around the globe. Given that MSDs are results of many interwoven factors and their prevalence rates vary among different body sites, this review study aims to investigating the causes, prevalence and intervention means for MSDs among port workers. The study entailed a sizeable search of academic databases. Based on reviewed literature, the present study summarized lower back as the most affected body part by MSDs, followed with lower back, neck, shoulder and joint among port workers. Further, ergonomic studies and applications designed to prevent and alleviate port-related MSDs are badly proposed.

Keywords: Port worker · MSD · Prevalence · Crane · Intervention

1 Introduction

1.1 The Prevalence of Musculoskeletal Disorders (MSDs)

Musculoskeletal disorders (MSDs) are a wide spectrum of inflammatory and degenerative conditions that affect muscles, tendons, ligaments, joints, cartilage in upper and lower limbs, neck and lower back [1]. Typical symptoms are sprains, strains, back pain, tears and soreness. Musculoskeletal disorders (MSDs) have a detrimental effect on working-age people in all walks of line across the world. For USA alone, MSD-related disease affect more than one out of every two people at age 18 and over, and almost three out of four at age 65 and over. Among various MSDs, trauma, back pain, and arthritis are the three most common ones reported [2]. MSDs on the one hand, could directly jeopardize labor force's health and gradually sap people's working capability and productivity, which eventually could result in sick and injury leave, absenteeism and even early retirement [3]; On the other side, the treatment of MSDs could cause heavy healthcare burden for the whole society as substantial amount of money, medical resources and healthcare labor are required before MSDs are completed cured. According to OSHA, musculoskeletal disorders account for one out of every three dollars spent on American workers' compensation. Today employers pay as much as $20 billion a year on direct MSD-related cost, and about five times the number on indirect costs [4]. From an individual well-being perspective, it was found that port workers without MSD rated higher ($p < 0.00$) quality of life scale scores in terms of functional ability, mental and social aspects than those who suffered MSD [5]. The cause

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of MSDs are many. A report from UK pointed out that they can be directly caused by work that involves tasks such as repetitive motions, forceful exertions, non-neutral postures and vibrations [6]. Another British study confirmed that a high prevalence of work-related MSDs has been reported among workers involved with manual materials handling, unusual and restricted postures, repetitive and static work, vibration, and poor psychological and social conditions [7]. Besides, poorly designed workstations that require awkward body postures or repetitive movements are liable to cause upper limb disorders, repetitive strain injury, or other musculoskeletal conditions [8].

1.2 Port Worker Related MSDs

1.2.1 Port Worker Definition

Today, ports around the world are playing crucial role in international trade and economy. The operation of a port in an efficient and productive manner needs both modern equipment, good infrastructures and more importantly, healthy skilled employees such as port workers and machinery operators [9]. Therefore, it is important to define the term port worker before the port-related MSD review study. Although the role of port worker is evolving with the modernization of port in the last century, the term port worker is still widely used to designate blue collar workers engaged in the manual labor within port such as loading and unloading of cargo ships, handling of goods at docks or warehouses, auxiliary work such as checking, storage and transportation of cargo [10]. Another major group of port workers are various machinery operators including drivers of straddle carriers, fork-lift trucks, freight-container tractors, and overhead and mobile cranes [11]. Besides, tallyman, foreman who engage into some extent of office work are also labeled as port workers. As a conclusion, labor force of a modern port is typically composed of the following professionals: general workers, machinery operators, signalmen, lashers, tallymen and foremen.

1.2.2 Port Labor-Related MSDs

Any types of industrial workers face the risk of being exposed to musculoskeletal disorders, and port worker is not an exception. A Brazilian research revealed that ergonomic and psychosocial risks such as awkward posture, demanding work shifts, excessive tasks and movements, stressful working conditions and repetitive training together lead to the high frequency of occurrence of musculoskeletal disorders among dock workers [12]. According to another Brazilian study, occupational diseases which affect spine and joints, are widely self-reported by maritime industry workers from a southeastern Brazilian port [13].

Besides, for all port-based machinery operators, they are also exposed to prevalent MSDs and some study even pointed out that machinery operators have higher rates of musculoskeletal injuries than non-operators [14]. Take crane operator for example, everyday they must operate machines with extreme cautions and precision by following a certain pace to accomplish their task. Meanwhile they must ensure the safety of the containers and avoid any damage or loss. As a result of such physically and mentally demanding labor, port crane operators have been reported by many studies to suffer alerting prevalence of musculoskeletal disorders in lower back arms, neck, shoulder [15, 16]. Another study found that except the exacting nature of machinery operation work, other factors include static sitting, awkward postures, and exposure to whole body vibration jointly contributed to the occurrence of work-related musculoskeletal disorders among port equipment operators [14]. Further, Boveni and his colleagues investigated the occurrence of low back pain (LBP) among Italian straddle carrier, forklift, and crane operators who were intensively exposed to both whole-body vibration (WBV) and postural load [11]. The result provided sufficient supports to the finding that machinery-seated WBV exposure and non-neutral trunk postures could impose long-term detrimental effects on operator's lower back health. Another study from the Netherlands indicated that crane operators were intensively interfered by back disorders and the cause could be attributed to exposure to whole-body vibration and strained posture [17]. Moreover, Bongers and her colleagues emphasized that the combination of long-time exposure to whole-body vibration, an awkward posture, and adverse climatic conditions are strongly associated with spinal disorders, particularly intervertebral disc disorders [18].

1.3 Research Question

However, compared to ample academic studies on other job-associated MSDs, port-related MSDs have been, to large extent, overlooked. Scrutiny of previous experimental and review studies about MSDs on port workers are generally scarce and patchy. Even though similar review study has confirmed the occurrence of musculoskeletal disorders in shipyard industry, where employees reported low back pain as the most prevalent health complaint [19], no such sort of work has been done to investigate the prevalence of MSDs among port industry. Therefore, the objective of this review is to list all port-related MSDs in an order of severity as well as investigate which parts of human body are the most affected by MSDs after years' port career. Further, this review will also try to unveil what are the tasks that primarily cause each type of MSD. The research subject of this review is identified as port worker.

2 Methodology

2.1 Criteria for Inclusion

The criteria for inclusion are journal and conference papers as well as reports in English language within last three decades. The research subject is limited to port worker, as defined in the paragraph 1.2. No restrictions were placed on age, gender, race or socioeconomic status. Only articles that documented the prevalence of MSD and its risk factors were considered.

Key words: Musculoskeletal, lower back pain, port, crane were used to search related literatures (Fig. 1).

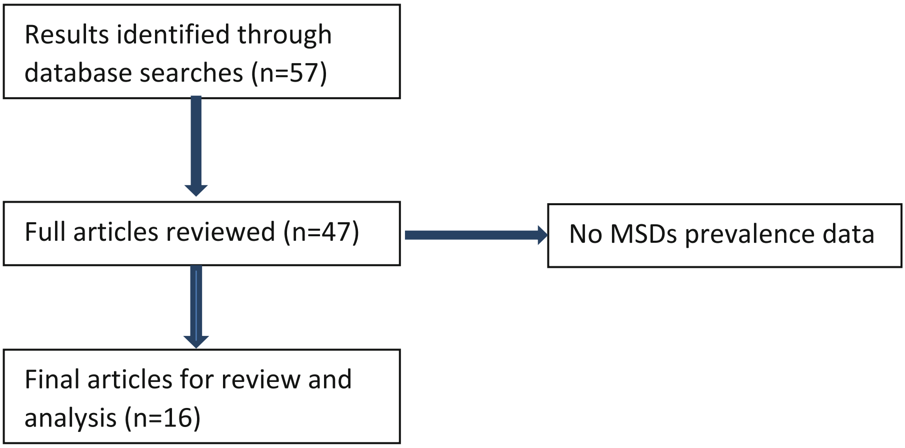

Fig. 1. Flow chart of literature research

3 Results

The following online databases were investigated: MEDLINE, PubMed and NIOSH-TIC which provide a medical perspective; Google Scholar Elsevier, ResearchGate, Taylor & Francis Online, Springer which provide a wide-spectrum perspective.

Table 1 categorizes MSDs into 10 types based on body parts. It lists the prevalence of MSDs in percentage, the subjects of research, the sample size of the research, the countries involved, years, authors and interventions.

Though the data is collected from various port-related professionals from different countries, it can be seen from Table 1 that lower back is ranked as the most MSD-affected body part in terms of percentage. It always has the highest percentage compared to other bodies. Following lower back are neck, shoulder and joint for dock workers. For operators, neck is always reported as the second most affected part by MSD. Besides, the adverse effects of MSDs on other body parts including hip, thigh, limbs, feet are also noticeable.

3.1 Lower Back

Lower back pain has been intensively discussed in the review paper collected. A Brazilian study showed that lower back pain has the highest prevalence rate, which was 38.3% among dock casual workers. In Iran, the prevalence rate of lower back pain among port crews was 32.9%, again representing the most critical MSD. A Greek study revealed that the LBP prevalence was 39.3% among port-based blue collars. For machine operators, they suffered more from LBP according to many studies. In studies from New Zealand, USA and Hong Kong, the LBP prevalence were considerably high: 0.86, 0.599, 0.88, indicating an alerting health threat to a variety of machine operating professionals.

Table 1. Percentage-based MSDs summary

International studies on the prevalence of MSD among port workers						
Body part	Prevalence	Subjects	Sample size	Country	Year	Authors
Lower back	0.388	Dock worker	152	Brazil	2012	Almeida et al.
	0.329	port crew	722	Iran	2004	Saraji et al.
	0.393	port blue collar	853	Greece	2006	Alexopoulos et al.
	0.86	Machine operator	6890	New Zealand	2010	Edwin et al.
	0.88	Grab uploader driver		Hong Kong	1999	Courtney et al.
	0.599	Operating engineer	410	USA	1997	Zimmermann et al.
	0.91	Crane operator	209	Malaysia	2015	Kadir et al.
Neck	0.158	port crew	722	Iran	2004	Saraji et al.
	0.279	port blue collar	853	Greece	2006	Alexopoulos et al.
	0.77	Machine operator	6890	New Zealand	2010	Edwin et al.
	0.81	Grab uploader driver		Hong Kong	1999	Courtney et al.
	0.438	Operating engineer	410	USA	1997	Zimmermann et al.
	0.7	Crane operator	209	Malaysia	2015	Kadir et al.
Shoulder	0.188	port crew	722	Iran	2004	Saraji et al.
	0.197	dock worker	152	Brazil	2012	Almeida et al.
	0.64	Machine operator	6890	New Zealand	2010	Edwin et al.
	0.5	Grab uploader driver		Hong Kong	1999	Courtney et al.
	0.368	Operating engineer	410	USA	1997	Zimmermann et al.
	0.91	Crane operator	209	Malaysia	2015	Kadir et al.
Knee	0.264	port crew	722	Iran	2004	Saraji et al.
	0.32	Operating engineer	410	USA	1997	Zimmermann et al.
	0.91	Crane operator	209	Malaysia	2015	Kadir et al.
Ankle	0.168	port crew	722	Iran	2004	Saraji et al.
	0.186	Operating engineer	410	USA	1997	Zimmermann et al.
	0.91	Crane operator	209	Malaysia	2015	Kadir et al.

(*continued*)

Table 1. (*continued*)

International studies on the prevalence of MSD among port workers						
Body part	Prevalence	Subjects	Sample size	Country	Year	Authors
Feet	0.134	port crew	722	Iran	2004	Saraji et al.
Hand/Wrist	0.13	port crew	722	Iran	2004	Saraji et al.
	0.17	port blue collar	853	Greece	2006	Alexopoulos et al.
	0.297	Operating engineer	410	USA	1997	Zimmermann et al.
	0.9	Crane operator	209	Malaysia	2015	Kadir et al.
Leg	0.12	port crew	722	Iran	2004	Saraji et al.
	0.164	Operating engineer	410	USA	1997	Zimmermann et al.
	0.91	Crane operator	209	Malaysia	2015	Kadir et al.
Elbow	0.103	port crew	722	Iran	2004	Saraji et al.
	0.182	Operating engineer	410	USA	1997	Zimmermann et al.
	0.66	Crane operator	209	Malaysia	2015	Kadir et al.
Lumbar Sciatica	0.072	dock worker	152	Brazil	2012	Almeida et al.

3.2 Neck

Neck pain has also been given much attention from academic research on port workers due to its prevalence and severity. An Iranian study revealed that the prevalence rate of neck pain among port crews was 15.8%, another study from the Netherland and Greece revealed that the neck pain prevalence was 27.9% among blue collars. When it comes to machine operators, neck pain become more prevalent and serious. Researchers from New Zealand, USA and Hong Kong found that the neck pain prevalence were significantly high, respectively: 77%, 43.8%, 81%, thus constituting a considerable health-affecting risk.

3.3 Shoulder

Shoulder-related MSD is also critical considering its prevalence and severity among port activity practitioners. A Brazilian study unveiled that shoulder pain prevalence was 19.7% among dock casual workers, rendering it second most threatening MSD. Another Iranian study revealed that the prevalence rate of shoulder pain among port crews was 18.8%, other studies focusing on investigating how machine operation affected port worker's health revealed a higher prevalence of neck pain. For examples: machine operators and grab uploader drivers from New Zealand, USA and Hong Kong were found to suffer neck pain as prevalent as respectively: 64%, 36.8%, 50%, which led to a strong evidence that neck pain significantly affected machine operators' health.

3.4 Knee

Since knees suffer the most human weight, long time use of knees incurs severe MSD among pork workers. An Iranian study revealed that the prevalence rate of knee pain among port crews was 26.4%, making it the second most prevalent MSD. As for machine operators, the prevalence of knee pain is equally significant. An American study found that the knee pain prevalence rate was 32% among port operating engineers. Another study from Malaysia uncovered an even higher prevalence, 91% among machine operators sample from a Malaysian port.

3.5 Ankle

Ankle is another part that bears most human weight, therefore overuse of ankles causes chronic MSD among labor workers. A study from Iran revealed that the prevalence rate of ankle pain among port crews was 16.8%. When discussing the prevalence of ankle pain among machine operator, it becomes more considerable. A study from University of Iowa found that the ankle pain prevalence rate was 18.6% among port operating engineers. Besides, Malaysian researchers found an even higher prevalence of ankle MSD, 91% among machine operators.

3.6 Hand and Wrist

Since hand and wrist are frequently used during the process of most activities in port, excessive use of hand and wrist results in severe MSD among port professionals. A study from Iran revealed that the prevalence rate of hand and wrist pain among port crews was 13%. Another research from the Netherland and Greece revealed that the hand and wrist pain prevalence was 17% among blue collars in Greek ports. As regard to the prevalence of hand pain among machine operator, it was found to be much more critical. A study from University of Iowa found that the hand and wrist pain prevalence rate was 29.7% among port operating engineers while Malaysian researchers found an even higher prevalence of hand and wrist MSD, 90% among machine operators.

3.7 Leg

Leg burden of port worker is considerably high due to the exhausting nature of port labor. An Iranian study revealed that the prevalence rate of leg pain among port crews was 12%. As for machine operators, the prevalence of leg pain is equally significant. An American study found that the leg pain prevalence rate was 16.4% among port operating engineers. Another study from Malaysia revealed an even higher prevalence, 91% among machine operators sample from a Malaysian port.

3.8 Elbow

Elbow are frequently used in many port-related maneuvers, therefore excessive exertion of elbow could result in serious MSD among port practitioners. A study from Tehran University of Medical Sciences revealed that the prevalence rate of leg pain among port crews was 10.3%. For machine operators, the prevalence of leg pain is also critical. A University of Iowa study found that the elbow pain prevalence rate was 18.2% among port operating engineers. Another Malaysian study revealed an even higher prevalence of elbow pain, 66% among a machine operator sample.

3.9 Feet

The MSD symptom on feet has also been systematically discussed in academia. An Iranian study revealed that the prevalence rate of feet pain among port crews was 13.4%.

3.10 Lumbar Sciatica

Lumbar sciatica has also been analyzed in some port worker health-related research. One Brazilian study revealed that the prevalence rate of lumbar sciatica among port workers was 7.2%.

4 Discussion

4.1 Assessment of Port-Related MSDs

The present review study indicates that port workers have a prevalent suffering of symptoms in almost all body regions, which are designated as lower back, knee, shoulder, ankle, neck, feet, hand/wrist, leg, elbow back. Among those parts, lower back are considered to be the most affected body regions by MSD. All the selected papers have large subject size, which leads to a sound representativeness the magnitude of MSD amongst the port worker population.

It is also proven from this review work that longitudinal studies are necessary for a better estimation of MSD [20] regardless of the fact that they are expensive and difficult to conduct. Another issue that requires discussion is that although studies of the magnitude of the musculoskeletal problem in many industries have been performed for decades, the related definitions and methods are still inconsistent. As a result the estimations vary greatly between studies. For instance, ‘disorder’ is usually defined as a condition that comprises of both symptoms and signs as well as a positive diagnostic procedure [21], studies reporting musculoskeletal symptoms tend to have a higher prevalence than those about musculoskeletal disorders. Therefore, to compare studies, it is important to have a standard definition for musculoskeletal problems to clearly differentiate between musculoskeletal disorders and symptoms.

4.2 Intervention

As for effective intervention of musculoskeletal disorders, big national organizations such National Institute for Occupational Safety and Health (NIOSH), USA, Health and Safety Executive (HSE), UK and Occupational Safety and Health (OSH), New Zealand have implemented various single dimensional and multi-dimensional programs that employ medical, physical and psychosocial interventions [22]. Also an Iranian study urged that the most fundamental action to increase ports' productivity and reduce work related diseases and accidents is to implement protection for workers against any hazardous elements such as MSDs risk factors [23].

4.2.1 Ergonomics

The core of any intervention is the application of ergonomics. Ergonomics is a science dedicated to understanding of interactions among humans and other elements of a system, and practically fitting any tools, machines, environments the physical and mental abilities and limitations of humankind, thus contributing to the overall human well-being and quality of life [24, 25].

4.2.2 Position Correction

An Iranian study suggested that the best and sometimes the only way to correct awkward postures is correction of worker's back position.

4.2.3 Workstation

Both developed and developing countries realized that minor improvements in materials handling and workstations for preventing musculoskeletal disorders have significant impacts on safety and health promotion and on productivity increase [26]. Zimmermann's team suggested that acquisition of new equipment and continued changes in the ergonomics of equipment is a primary method of intervention when attempting to reduce WMDs among operating engineers. Edwin included some recommendations regarding equipment: the provision of seat adjustment accessories; improved ship's crane seating; processes to ensure cleanliness of windows; and efforts to address reflections on windows and computer screens. Also, Miller's team found that awkward postures avoidance can be addressed in the design by considering the workers' anthropometric characteristics, work behavior and the work environment when designing a cab [27]. Courtney and his team pointed out that view of the hold and work place design can be improved in the long term by modifying the cab structure [28]. Designing the equipment to fit the worker, rather than having the worker adjust to the equipment is essential in minimizing the risk of MSI and discomfort in heavy mobile machinery operators [27].

4.2.4 Therapy

Pinto and his colleagues pointed out that a physical therapy intervention is effective to improve the muscle flexibility and reduce pain of MSD among port workers [29]. A recent examination of systematic reviews on the effectiveness of workplace interventions to reduce musculoskeletal injuries proved the importance of worker participation in prevention programs [30].

5 Conclusion

In conclusion, this review study has demonstrated that the prevalence of MSD is high amongst dock worker population across the world. The highest prevalence of MSD is associated with low back, neck, and shoulders. Also, there is statistically significant differences in prevalence among age groups according to literature. Older and more experienced workers tend to suffer more severe and prevalent MSDs as a result of years of exposure to awkward posture and repetitive manual labor. Further studies, preferably longitudinal, are needed to more thoroughly investigate MSD among port worker, with a greater emphasis on ergonomic interventions. This would constitute a major step forward in prevention of MSD among port worker.

References

1. Punnett, L., Wegman, D.H.: Work-related musculoskeletal disorders: the epidemiologic evidence and the debate. J. Electromyogr. Kinesiol. **14**(1), 13–23 (2004)
2. Katz, S.I., Weinstein, S., Yelin, E.: The Burden of Musculoskeletal Diseases in the United States, pp. 778–781. United States Bone and Joint Initiative, Rosemont (2014)
3. Erick, P.N., Smith, D.R.: A systematic review of musculoskeletal disorders among school teachers. BMC Musculoskelet. Disord. **12**(1), 260 (2011)
4. Prevention of Work-Related Musculoskeletal Disorders (2014). https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=UNIFIED_AGENDA&p_id=4481
5. De Carvalho, M.P., Schmidt, L.G., Soares, M.C.: Musculoskeletal disorders and their influence on the quality of life of the dockworker. Work **53**(4), 805–812 (2016)
6. Summers, K., Jinnett, K., Bevan, S.: Musculoskeletal Disorders Workforce Health and Productivity in the United States. The Center for Workforced Health and Performance, Lancaster University, Lancaster (2015)
7. Nahit, E.S., Macfarlane, G.J., Pritchard, C.M., Cherry, N.M., Silman, A.J.: Short term influence of mechanical factors on regional musculoskeletal pain: a study of new workers from 12 occupational groups. Occup. Environ. Med. **58**(6), 374–381 (2001)
8. Workplace Safety and Health Management. The Health and Safety Authority, Dublin (2006)
9. Saraji, J., Hassanzadeh, M., Shahtaheri, M.F.: Evaluation of musculoskeletal disorders risk factors among the crew of the Iranian ports and shipping organization's vessels. Acta Med. Iranica **42**(5), 350–354 (2004)
10. Hooydonk, V.: Port Labour in the EU (2013)
11. Bovenzi, M., Pinto, I., Stacchini, N.: Low back pain in port machinery operators. J. Sound Vib. **253**(1), 3–20 (2002)
12. Almeida, M.C.V.D., Cezar Vaz, M.R., Soares, J.F.D.S., Silva, M.R.S.D.: The prevalence of musculoskeletal diseases among casual dock workers. Revista Latino-americana de Enfermagem **20**(2), 243–250 (2012)
13. Cavalcante, F.F.G., Gomes, A.C.N., Nogueira, F.R.A., Farias, J.L.M., Pinheiro, J.M.R., Albuquerque, E.V., Farias, A.L.P., Cabral, G.B., Magalhães, F.A.C., Gomide, M.: Occupational risks among dock workers in the port of Mucuripe, Fortaleza, Brazil. Ciênc. Saúde Coletiva **10**, 101–110 (2005)
14. Jorgensen, M., Kittusamy, N.K., Aedla, P.: Repeatability of a checklist for evaluating cab design characteristics of heavy mobile equipment. J. Occup. Environ. Hyg. **4**, 913–922 (2007)

15. Marion, E., Lee, P.: Musculoskeletal discomfort in crane and forklift operators in a New Zealand port. In: 16th Conference of the New Zealand Ergonomics Society (2010)
16. Yakub, N.W., Sidik, S.M.: Prevalence and contributing factors of job strain among crane operators in a port container terminal in Malaysia. Malays. J. Med. Health Sci. **10**(2), 8 (2014)
17. Bongers, P.M., Boshuizen, H.C., Hulshof, C.T.J., Koemeester, A.P.: Long-term sickness absence due to back disorders in crane operators exposed to whole-body vibration. Int. Arch. Occup. Environ. Health **61**(1), 59–64 (1988)
18. Bongers, P.M., Boshuizen, H.C., Hulshof, C.T., Koemeester, A.P.: Back disorders in crane operators exposed to whole-body vibration. Int. Arch. Occup. Environ. Health **60**(2), 129–137 (1988)
19. Charizani, F., Moysiadou, I., Siarkos, E., Alexopoulos, E.: Subjective risk assessment of industry employees. Rev. Clin. Pharmacol. Pharmacokinet. Int. Ed. **19**, 87–92 (2005)
20. Arrighi, H.M., Hertz-Picciotto, I.: The evolving concept of the healthy worker survivor effect. Epidemiology, pp. 189–196 (1994)
21. Violante, F., Isolani, L., Raffi, G.B.: Case definition for upper limb disorders. In: Occupational Ergonomics. Work Related Musculoskeletal Disorders of the Upper Limb and Back, London, Taylor & Francis, pp. 120–128 (2000)
22. Boocock, M.G., McNair, P.J., Larmer, P.J., Armstrong, B.: Interventions for the prevention and management of neck/upper extremity musculoskeletal conditions: a systematic review. Occup. Environ. Med. **64**(5), 291–303 (2007)
23. Saraji, J.N., Hassanzadeh, M.A., Pourmahabadian, M., Shahtaheri, S.J.: Evaluation of musculoskeletal disorders risk. Acta Med. Iranica **42**(5), 350–354 (2004)
24. Chapanis, A.: Human Factors in Systems Engineering. Wiley, New York (1996)
25. Karwowski, W.: Ergonomics and human factors: the paradigms for science, engineering, design, technology and management of human-compatible systems. Ergonomics **48**(5), 436–463 (2005)
26. Kogi, K., Kawakami, T.: Current research, ergonomics. Environ. Manag. Health **8**(3), 188–190 (1997)
27. Miller, L., Gariepy, C.: Heavy mobile equipment-ergonomics and the prevention of musculoskeletal injuries. In: BC Mines Conference (2008)
28. Courtney, J.A., Chan, H.A.: Ergonomics of grab unloaders for bulk materials handling. Int. J. Ind. Ergon. **23**(1), 61–66 (1999)
29. Pinto, A., Risson, J., Mattos, D., Reis, P., Merino, E., Moro, A.: Proposal for intervention in company: study workers with of a road-rail port of one city in the extreme south of Brazil. In: Proceedings 19th Triennial Congress of the IEA (2015)
30. Robertson, M., Amick III, B.C., DeRangoc, K., Rooneyd, T., Bazzanid, L., Harriste, R.: The effects of an office ergonomics training and chair intervention on worker knowledge, behavior and musculoskeletal risk. Appl. Ergon. **40**(1), 124–135 (2009)

Ergonomic Evaluation of Risk Level by Exposure to Forced Postures in Cattle Slaughterhouse Workers in Ecuador

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Abstract. Nowadays, worldwide work related musculoskeletal disorders are considered a serious public health problem because they affect a high proportion of the economically active population, incapacitating the affected individual temporarily or permanently for their professional activities. So, greater attention should be paid to the ergonomic risks in the working population. The objective of this study is to determine the risk level do to forced postures of workers in the slaughter area of a representative company of the Ecuadorian meat industry. The risk factors are analyzed through direct observation, videos and the application of the Rapid Entire Body Assessment and Rapid Upper Limb Assessment methods. The results show a high-risk level caused by forced postures, highlighting the importance of prevention programs to improve the working conditions, that can minimize the damage and improve the life quality of workers and the productivity of small industries in developing countries.

Keywords: RULA · REBA · Forced postures · Risk level

1 Introduction

Actually, musculoskeletal disorders (MSDs) are around the 40% of the total cost compensated for occupational diseases and injuries in the industries [1]. So, they are considered a serious public health problem because they affect a high proportion of the economically active population, incapacitating the individual temporarily or permanently for their professional activities [2].

MSDs are considered a major cause of injuries and physical disabilities in both developed and developing countries and are also the main cause of illness and absence from work [3], related mainly to the existence of biomechanical factors such as the application of force, repetitive movements, forced and static postures, and others linked to working environment conditions [4]. In addition, ergonomic conditions can be aggravated by the need to support an excessive workload [5]. The most important physical risk

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factors to which workers are exposed are forced postures, repetitive movements, cargo handling and the manipulation of significant forces [4].

Follow-up studies conducted in industrial environments shows that very few workers are totally free of musculoskeletal pain and that the transition from the absence of pain or a pain of minor importance, to a more severe pain was influenced by physical and psychosocial factors of the workplace, along with individual and health related factors [6]. Therefore, the design of jobs requires an evaluation that considers the physical characteristics of the operator and the type of work to be carried out. When designing a workplace, several ergonomic factors must be taken into account, including the height of the head and shoulders, the reach of the arms, the height of the elbow and hand, the length of the legs and the size of the hands among others. Highlighting the need to perform anthropometric studies of the workers in each workplace [6].

The National Institute of Occupational Safety and Health in its research, links the problems of the spine with forced postures, revealing that the most frequently reported areas for musculoskeletal pain are in the back exceeding the 79% [6].

The repeated adoption of uncomfortable postures generates fatigue and in the long term can cause MSD such as wrist and shoulder tendinitis, carpal tunnel syndrome, and lateral epicondylitis. So greater attention should be paid to the prevention of these ergonomic risks in the working population, with special emphasis on manuals works, where workers with the most disadvantaged personal and work characteristics are concentrated [7], that is the case of cattle slaughterhouse where the physical load required for the jobs are very high. In this type of company, the diagnosed musculoskeletal disorders are numerous, encompassing occupational diseases, accidents and overexertion, however, research related to this sector is scarce [8].

The objective of this study is to determine the risk level do to forced postures, to which workers in the slaughter area of a company representative of the Ecuadorian meat industry, are exposed.

2 Methodology

2.1 Steps for the Application of the Ergonomic Methods

The present investigation is carried out in the slaughter area of an important Ecuadorian industry of the meat sector located in the city of Ambato. Through the analysis of the slaughter operations in which, for the execution of tasks, workers are required to adopt forced or uncomfortable positions such as: standing for long periods with a hunched back, twisting the trunk, lifting the arms and flexing the extremities. The risk factors are analyzed through direct observation and analysis of videos and the application of the Rapid Entire Body Assessment (REBA) and Rapid Upper Limb Assessment (RULA) methods. It is important to mention that two or more methods must be applied to validate and reinforce the results when it comes to risk analysis [9].

The techniques used for the evaluation of ergonomic risks are based mainly in observation [10]. The steps to complete the evaluation are:

- Determine the work cycles and observe the worker during several of these cycles. If the cycle is too long or there are no cycles, evaluations is made at regular intervals.

- Select the positions to be evaluated, considering those that in the opinion of the evaluator, suppose a greater postural load, either because of their duration, their frequency or because they present a greater deviation with respect to the neutral position.
- Decide if left or right side of the body will be evaluated. In case of doubt, both sides will be analyzed.
- Take the required angular data. Photographs can be taken from the appropriate points of view to make the measurements (see Fig. 1).
- Calculate the scores for each part of the body. Use the corresponding table for each member.
- Obtain the partial and final scores of each method to define the risk existence and establish the action level. If required, determine what corrections should be adopted. Review the scores for the different body parts to decide where corrections are necessary [11].

Fig. 1. Evaluation of body angles in work positions.

2.2 Rapid Entire Body Assessment (REBA)

This method allows scoring 144 possible posture combinations (including trunk, neck, legs, arms and wrists). Additional considered factors are load, coupling and frequency. After the analysis, the method provides an overall score and classification in five action levels for the ergonomic intervention. However, the user must be able to identify his critical work activity to be able to make the evaluation, which could be difficult depending of the body part and the risk assessed [12].

Some of the advantages of the REBA method are:

- Is a sensitive tool for musculoskeletal risks when classifying the body into parts (wrist, arm, forearm, neck, trunk and legs).
- Is useful for risk assessment of manual tasks.
- Proposes the prioritization of corrective measures in accordance with the risk assessment and the risk level [13].

2.3 Rapid Upper Limb Assessment (RULA)

This method was developed for use in ergonomic investigations in workplaces where there were work related disorders in the upper extremities. It provides a global score that considers the postural load throughout the body with special attention to the neck, trunk, shoulders, arms and wrists. The overall score also takes into account the used force and the repetitiveness of the movements [5].

3 Results

Once the jobs in the slaughter area have been identified, it is determined that 12 tasks involving 22 workers must be evaluated for risk factor caused by forced postures. For the selected workers sample the average height is 162.4 cm, the average age is 42 years old and the average weight is 73.3 kg. Tables 1 and 2 shows the results of the evaluation performed when applying the REBA and RULA methods respectively.

Table 1. Results of the evaluation of forced postures applying the REBA method.

Level	0	1	2	3	4
Score	1	2–3	4–7	8–10	11–15
Risk Level	Negligible	Low	Medium	High	Very High
Action Level	Not necessary	May be necessary	Necessary	Necessary soon	Necessary now
% of Workers	–	27	32	41	–

Table 2. Results of the evaluation of forced postures applying the RULA method.

Level	0	1	2	3
Score	1–2	3–4	5–6	7+
Risk Level	Negligible	Low	Medium	Very High
Action Level	Not necessary	Further investigation	Necessary soon	Necessary now
% of Workers	–	27	23	50

The scores of both REBA and RULA in this study showed very high levels of biomechanical risk for workers in the meat industry, where 50% of workers are exposed to high risk levels by the positions adopted during the execution of their labors. Being the main causes, the high values of trunk inclination, flexion of upper extremities and lifting the arms above the height of the shoulder.

Approximately, 25% of workers are exposed to medium risk levels due to exposure to forced postures, as result of postural changes, limb flexion and trunk tilt. The required actions in these cases are to perform further investigation and to make changes soon. The rest have a low risk level, and they work mainly where the activities are performed in an upright trunk position, with little knee flexion and there is no twisting or lateral tilt of trunk or neck. There are no evaluations with negligible risk level where actions are not required.

Regarding the biomechanical conditions in the working area, they are deficient, due to the poor distribution and design of most of the workstations [14]. It should also be considered that the absence of breaks can cause the workers to lower the standards of accuracy and reliability, which can lead to an increase in the frequency of errors and accidents [2].

A high prevalence of reported musculoskeletal symptoms, in the workers who have stated discomfort or persistent pain in the last 12 months: 30% neck level, 74% at back level, 87% in the arms, 74% in the forearms, 65% in the wrists and 48% in the legs. Verifying the existence of frequent discomfort at the upper extremities and back, in concordance with the obtained results.

Several studies have confirmed that a high prevalence of musculoskeletal symptoms are related to poor quality working conditions, poor design of workstation and tools, mental stress and biomechanical factors [1]. In the studied industry, the physical loads present in the jobs are very high, so the musculoskeletal disorders diagnosed are numerous, including occupational diseases and the accidents due to overexertion [8].

4 Discussion

The evaluations carried out in the slaughter area of workers in an Ecuadorian meat industry with slaughterhouse confirm the urgent need to carry out ergonomic interventions to modify the current workstations conditions. It is necessary to introduce changes such as adjustable working heights, lifting platforms that allow access to all parts of the animal without forced postures on trunk or arms, lifting base according to activity and size of the worker to improve the critic positions. In addition, short breaks, for stretching exercises, must be implemented, to allow the muscles to recover from fatigue and to reduce work stress. Furthermore, the workers should be trained on the use of the tools and equipment they used.

In most workstations, cutting tasks are performed with the adoption of forced postures in the back and upper extremities, and there is also application of force in the use of manual tools such as knives and saws. Therefore, it is necessary to provide the worker with ergonomic cutting tools that avoid forced postures and minimize the magnitude of the used force, with suitable dimensions in cuffs and cutting elements, being well sharpened and maintained.

This research highlights the importance of prevention programs that can minimize the damage of workers. Because the reduction of MSDs and the improvement of the working conditions of small industries in developing countries will have a considerable effect on the promotion and maintenance of workers' quality of life and will lead to higher productivity.

Additionally, according to what was reported by the application of the REBA method, it can be observed that the tool is applied on a par with other method (RULA) to obtain a comprehensive evaluation and identify all the risk factors to which workers are exposed in the exercise of their activities.

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References

1. Van, L., Chaiear, N., Sumananont, C., Kannarath, C.: Prevalence of musculoskeletal symptoms among garment workers in Kandal province, Cambodia. J. Occup. Health **58**(1), 107–117 (2016)
2. Lourinho, M.G., Negreiros, G.R., Almeida, L.B.D., Vieira, E.R., Quemelo, P.R.V.: Riscos de lesão musculoesquelética em diferentes setores de uma empresa calçadista. Fisioterapia e Pesquisa **18**, 252–257 (2011)
3. Veisi, H., Choobineh, A., Ghaem, H.: Musculoskeletal problems in iranian hand-woven shoe-sole making operation and developing guidelines for workstation design. Int. J. Occup. Environ. Med. **7**(2 April), 725–787–797 (2016)
4. Márquez Gómez, M., Márquez Robledo, M.: Factores de riesgo biomecánicos y psicosociales presentes en la industria venezolana de la carne. Ciencia & trabajo **17**, 171–176 (2015)
5. Vazquez-Cabrera, F.: Ergonomic evaluation, with the RULA method, of greenhouse tasks of trellising crops. Work **54**(3), 517–531 (2016)
6. Muñoz Poblete, C., Vanegas López, J., Marchetti Pareto, N.: Factores de riesgo ergonómico y su relación con dolor musculoesquelético de columna vertebral: basado en la primera encuesta nacional de condiciones de empleo, equidad, trabajo, salud y calidad de vida de los trabajadores y trabajadoras en Chile (ENETS) 2009–2010. Medicina y Seguridad del Trabajo **58**, 194–204 (2012)
7. González-Galarzo, M.C., García, A.M., Gadea Merino, R., Martínez Martínez, J.M., Velarde Collado, J.M.: Exposición a carga física en el trabajo por ocupación: una explotación de los datos en matriz empleo-exposición española (MATEMESP). Revista Española de Salud Pública **87**, 601–614 (2013)
8. Laboral, I.D.S.Y.S.: Riesgos y Medidas Ergonómicas en el Sector Cárnico (2015). www.carm.es/web/servlet/integra.servlets.Blob?ARCHIVO=FD-108.pdf&TABLA=ARCHIVOS&CAMPOCLAVE=I
9. López Torres, B.P., González Muñoz, E.L., Colunga Rodríguez, C., Oliva López, E.: Evaluación de Sobrecarga Postural en Trabajadores: Revisión de la Literatura. Ciencia & trabajo **16**, 111–115 (2014)
10. Li, G., Buckle, P.: Current techniques for assessing physical exposure to work-related musculoskeletal risks, with emphasis on posture-based methods. Ergonomics **42**(5), 674–695 (1999)
11. Diego-Mas, J.A., Poveda-Bautista, R., Garzon-Leal, D.C.: Influences on the use of observational methods by practitioners when identifying risk factors in physical work. Ergonomics **58**(10), 1660–1670 (2015)
12. Chander, D.S., Cavatorta, M.P.: An observational method for Postural Ergonomic Risk Assessment (PERA). Int. J. Ind. Ergon. **57**, 32–41 (2017)
13. Ali, A., Qutubuddin, S., Hebbal, S., Kumar, A.: An ergonomic study of work related musculoskeletal disorders among the workers working in typical Indian saw mills. Int. J. Eng. Res. Dev. **3**(9), 38–45 (2012)
14. Zegarra, R., Andara, M.: Análisis de Riesgos Ergonómicos, a través de los métodos REBA y RULA (2012)

Applied Forces and sEMG Activity Contribution to Risk Assessment for Assistance Workers Helping Passengers with Restricted Mobility

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Abstract. As air travel grows the numbers of passengers with varying degrees of motor disability have grown too. The aim of this study is to analyze the task of pushing Passengers with Restricted Mobility (PRM) on three different wheelchairs (WhCh) currently supplied to PRM service of a Rome airport. The WhChs differed in their width, weight and wheels dimension. We investigated initial and sustained forces, according to the Annex D of ISO 11228-2 standard, by means of a digital dynamometer. Surface Electromyography (sEMG), was also recorded bilaterally from Erector Spinae and Anterior Deltoid only in the initial phase.

Pushing forces, together with sEMG, may help to have a better understanding of the task requirements and a more detailed risk assessment.

The use of both sEMG and applied forces values can be used also to help PRM airport services in choosing the wheelchair that best fit with the passenger to handle and in order to reduce the biomechanical load in PRM assistance workers.

Keywords: Push and pull · Wheelchair · Ergonomic · Risk assessment PRM

1 Introduction

The action of pushing and pulling involves exerting force using the hands in a horizontal direction (away from the body for pushing and towards the body for pulling). Sometimes, the force exerted is not perfectly horizontal but may include a vertical component, based on the position of the hands during pushing/pulling [1].

There are several risk factors that influence push and pull activity, among the main are: (1) friction (2) grade/slope: several authors [2–4] suggest slope less than 3.5% grade (3) wheels: the greater the pressure of the wheels of a trolley, the stiffer the surface along

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which the movement is made, the lower the push/pull force required [3, 5–7]. Similarly, the larger the diameter of the wheels, the lower is the pushing/pulling force required to push/pull the cart. Moreover, smaller wheels can become more easily blocked by bumps, holes, and other obstacles on the floor compared to larger wheels [10] (4) swiveling of wheels [5, 8] (5) weight on the cart: for a given cart and floor surface, as the weight of the cart increases the force required to push/pull a cart increases linearly [11] (6) handle height (7) trunk posture (8) foot placement (9) pushing/pulling frequency (10) pushing/pulling distance.

The action of pushing and pulling involves the following three stages:

I. Initial stage: the application of the force necessary to set the object in motion;
II. Central stage: the application of a sustained force, of less than the initial force, necessary to keep the object moving;
III. Final stage: the application of the force necessary to bring the object to rest.

Most articles found in the literature focus on the study of the initial and sustained forces.

The aim of the study is to compare pushing forces and muscle activity, recorded by means of surface electromyography (sEMG), of three different wheelchairs currently in use at the Rome airport in order to choose the one that involves the fewest biomechanical load in PRM assistance workers.

1.1 Task Description

The workers provide assistance to PRMs accompanying them and any baggage: i) in departure, from their arrival at the air terminal (at the Terminal or at the railway station or at a multi-floor carpark, etc.) to their seat on the airplane; ii) in arrival, from their seat on the airplane to their ground destination; iii) in transit between an arriving flight and subsequent departure on another flight. The activities of the operators are performed throughout the whole airport using a wheelchair (made available by the assisting company or, rarely, the personal wheelchair of the PRM), with the exception of some special kind of assistance for which there are minivans equipped to carry disabled passengers.

2 Materials and Methods

2.1 Experimental Setup

The initial and sustained forces were measured on a flat surface, as the limits proposed for pushing and pulling do not take into account actions performed on sloping surfaces [12]. Two different pulled weights were tested, 55 kg and 100 kg. For initial forces, three starting position of the steering wheels were also tested (180°, 90°, 0°) for the three wheelchairs (WhCh) investigated (A, B, C). Force measurements were taken on a surface with the same characteristics as the airport floor. We chose a 60 m path to be able to create the most unfavorable conditions for the operator.

All three WhCh models were in excellent working order and all the wheels were at the pressure recommended by the manufacturer. Table 1 shows technical features of the three WhChs. Table 2 resumes the experimental setup.

Table 1. Technical features in cm (weight in Kg) of the three tested wheelchairs

WhCh	Handle height	Handle width	Anterior wheel Ø	Posterior wheel Ø	Weight
A	89	50	20	60	24
B	91	53	18	60	22.8
C	89	39	19	30	16.9

Table 2. Experimental setup

Wheelchair A						Wheelchair B						Wheelchair C					
55 kg			100 kg			55 kg			100 kg			55 kg			100 kg		
180°	90°	0°	180°	90°	0°	180°	90°	0°	180°	90°	0°	180°	90°	0°	180°	90°	0°

2.2 Surface Electromyography

Five male subjects were enrolled. Their average (SD) age, height and weight were respectively 41.8 years (3.5), 180.2 cm (6.6) and 83.8 kg (11.3). None of them had any history of either musculoskeletal disorders or neurological diseases.

Electrical muscle activity was recorded using a 16 channel Wi-Fi surface electromyography system (FreeEMG, BTS SpA, Milan, Italy) at a sampling frequency of 1 kHz. After skin preparation, surface electromyographic (sEMG) signals were detected from each muscle by two Ag/AgCl pre-gelled disposable surface electrodes (H124SG, Kendall ARBO, Donau, Germany) which had a detection surface of 10 mm (gelled). Electrodes were placed bilaterally over the muscle belly of Deltoideus Anterior (DAdx, DAsx) and Erector Spinae (ESdx, ESsx) in the direction of the muscle fibers, according to the Atlas of muscle innervation [13] and to the SENIAM indications [14] Data were processed using MATLAB R2017b software (vers. 9.3.0, MathWorks, Natick, MA, USA).

The sEMG signals were filtered with a bandpass filter (20–450 Hz) with an IIR digital Butterworth filter of 9°. Afterward, to obtain linear envelope, signals were rectified and filtered with an IIR low pass Butterworth filter of 3° with a cut frequency of 10 Hz. The Root Mean Square (RMS) and the Peak value (PK) of each muscle in each condition were measured as percentage of Maximum Voluntary Contraction (%MVC).

2.3 Pushing Forces

Pushing forces measurement was performed according to Annex D of ISO 11228-2 [12].

The initial force under all conditions and for each wheelchair was measured both with the steering wheels facing the direction of travel (hereinafter 0° position) and with the steering wheels at 90° to the direction of travel (hereinafter 90° position), as specified in Annex D of ISO 11228-2. In order to consider a further condition that could occur in the field, the initial force was also measured with the steering wheels in the opposite direction to that of travel (hereinafter 180° position).

Five measurements of the initial force and the sustained force were taken under all wheel starting positions, for each condition and for each WhCh, in accordance with that specified in Annex D of ISO 11228-2.

The initial and sustained forces were measured using a digital dynamometer with a maximum load of 50 kg.

The dynamometer was connected solidly to the wheelchairs and its load cell was placed on a hard surface secured to the wheelchair to prevent any attenuation of the values due to absorption of the force.

The dynamometer recorded the forces in kg on a USB pen drive. The data downloaded from the pen drive allowed us to highlight clearly and objectively the peak values recorded for each of the test conditions, from which we calculated the average value. The initial force coincides precisely with the absolute peak force shown by the dynamometer for each data acquisition. All the peak values obtained in each of the 5 tests with all the WhCh and under each of the three initial conditions were used to calculate an average initial force.

For the average sustained force, however, we did as follows: for each data acquisition, we ignored the first 5 samples following the peak value, insofar as they were still part of the pushing stage, and the last 5 samples before the end of data acquisition, insofar as they were part of the braking action. The average value of the sustained force is based on 15 acquisitions.

We chose maximum reference limit of 14 kg for the initial force and 5 kg for the sustained force, for activity along a path of 60 m (this distance was identified according to technical standards as the highest reference limit available). We also identified an action frequency of 30 min (an approximation of operating conditions) and a wheelchair handle height of 89 cm, given that this is the closest reference value for the height of the handles from the ground for the wheelchairs tested. According to the tables of Snook and Ciriello [15], these values protect 90% of the female working population. We took into account the aforementioned limits insofar as, of all the conditions indicated in the tables of Snook and Ciriello [15], they most closely resembled the real operating conditions of AdR Assistance personnel.

2.4 Statistical Analysis

All the analyses were performed using SPSS Statistics 17.0 software (SPSS Inc., Chicago, IL, USA). The mean and standard deviations (SD) of applied forces (initial and sustained) and sEMG (initial) were calculated for each weight, wheelchair and starting position of the steering wheels.

For sustained forces, a one-way repeated-measures analysis of variance (ANOVA) was performed for each weight to determine whether there was a significant effect of the wheelchair for both investigated weight on the mean values of the parameters. A post-hoc Tukey's test between pairs of wheelchair was applied separately for the two weights investigated.

For initial forces and sEMG a multivariate analysis of variance (MANOVA) was performed to determine whether there was a significant effect of the wheelchair and the starting position of the steering wheels for both investigated weight on the investigated parameters (forces, RMS, PK). A post-hoc Tukey's test between each different starting position was used to detect any significant differences between the three wheelchairs for both investigated weights.

P-values lower than 0.05 were considered statistically significant.

3 Results

3.1 Pushing Forces

Tables 3 and 4 show statistical analysis of sustained and initial forces.

ANOVA for initial forces showed statistically significant results among the three WhCh investigated for both weights.

MANOVA for initial forces showed statistically significant results Between A Vs C in all the experimental conditions. The comparison between WhCh A Vs B showed statistically significant results in all comparisons except for pushing 100 kg at 0°. The comparison between WhCh B and C didn't show statistically significant results except for pushing 100 kg with the steering wheels at 180°.

Table 3. Post hoc One Way ANOVA for sustained forces. Bold values indicate $p < 0.05$

Weight (Kg)	A Vs B	A Vs C	B Vs C
55	**<0,000**	**<0,000**	**<0,000**
100	**<0,000**	**<0,000**	**<0,000**

Table 4. Post hoc MANOVA for initial forces. Bold values indicate $p < 0.05$

Weight (Kg)	Position	A Vs B	A Vs C	B Vs C
55	180°	**0,001**	**<0,000**	0,079
55	90°	**<0,000**	**<0,000**	0,168
55	0°	**0,001**	**0,005**	0,543
100	180°	**0,001**	**0,000**	**0,024**
100	90°	**0,001**	**0,002**	0,791
100	0°	0,053	**0,001**	0,148

3.2 Surface Electromyography

Tables 5, 6, 7 and 8 show mean (±SD) peak values of the four muscles activities investigated with two weights (55 and 100 kg) and three positions of the steering wheels (180°, 90°, 0°).

The comparison showed no statistically significant difference. Nevertheless, it is possible to observe trends. A WhCh showed the lowest mean peak values for all investigated muscles in the heaviest conditions (pushing 100 kg with the steering wheels at 180° and 90°). Furthermore, A WhCh showed the lowest mean peak values pushing 55 kg at 90°. There are no differences among the three wheelchairs pushing both weights at 0°.

Table 5. Table show mean (±SD) Peak values for right Deltoideus Anterior (%MVC)

Weight (Kg)	Position	A	B	C
55	180°	19.9 ± 6.8	21.6 ± 6.7	20.7 ± 3.9
55	90°	25.2 ± 10.2	35.3 ± 14.8	27.3 ± 8.5
55	0°	19.1 ± 9.2	18.9 ± 5.5	18.9 ± 6.1
100	180°	25.6 ± 10.7	27.1 ± 11.6	31.2 ± 7.2
100	90°	28.7 ± 8	33.5 ± 8.6	38.8 ± 13.8
100	0°	27.3 ± 11.3	27.9 ± 10.3	29.7 ± 8.8

Table 6. Table show mean (±SD) Peak values for left Deltoideus Anterior (%MVC)

Weight (Kg)	Position	A	B	C
55	180°	21.2 ± 5.8	25.2 ± 13.2	17.8 ± 3.5
55	90°	21.8 ± 7.4	32.3 ± 8.8	22.9 ± 4.6
55	0°	21.1 ± 9.2	18.2 ± 4.1	18.3 ± 5.8
100	180°	26.9 ± 12.4	28.6 ± 11.9	27.9 ± 11.3
100	90°	32.9 ± 11.6	43.6 ± 14	41 ± 10.9
100	0°	33.2 ± 16	32.5 ± 8	28.6 ± 11.9

Table 7. Table show mean (±SD) Peak values for right Erector Spinae (%MVC)

Weight (Kg)	Position	A	B	C
55	180°	18.4 ± 6.4	18.5 ± 7.5	18.5 ± 7.3
55	90°	18.2 ± 5.7	24.9 ± 10.3	21.5 ± 7.2
55	0°	17.8 ± 7.1	17.6 ± 6.9	17.1 ± 5.3
100	180°	19.5 ± 5.6	23.6 ± 8.2	23.5 ± 7.7
100	90°	20.7 ± 7.7	22.2 ± 10.4	22.7 ± 6.5
100	0°	23.4 ± 8.1	23.4 ± 9.6	21.7 ± 6.5

Table 8. Table show mean (±SD) Peak values for left Erector Spinae (%MVC)

Weight (Kg)	Position	A	B	C
55	180°	19.1 ± 5.6	24.7 ± 8.8	19.7 ± 5.2
55	90°	18.9 ± 5.7	22.4 ± 3.2	19.9 ± 2.8
55	0°	19.2 ± 6.5	18.9 ± 3.4	20.9 ± 6.6
100	180°	17.2 ± 8.4	18.9 ± 5.9	20.6 ± 6.9
100	90°	18.4 ± 4.6	23.5 ± 6.8	24.1 ± 9.2
100	0°	16.6 ± 6.3	17.6 ± 6.1	19.6 ± 8.1

Tables 9, 10, 11 and 12 show mean (±SD) RMS values of the four investigated muscles with two weights (55 and 100 kg) and three steering wheels positions (180°, 90°, 0°).

Table 9. Table show mean (±SD) RMS values for Right Deltoideus Anterior (%MVC)

Weight (Kg)	Position	A	B	C
55	180°	11.9 ± 2.5	13.6 ± 2	11.9 ± 1.4
55	90°	14 ± 4.8	19.9 ± 8.8	15 ± 2.9
55	0°	11.2 ± 3.8	11.5 ± 2.3	11.6 ± 3.6
100	180°	15.2 ± 4.5	16.5 ± 3.4	17.5 ± 3.2
100	90°	17.8 ± 4.6	19.9 ± 3.3	21.9 ± 4.7
100	0°	15.5 ± 4.5	16.3 ± 5.7	17 ± 3.8

Table 10. Table show mean (±SD) RMS values for Left Deltoideus Anterior (%MVC)

Weight (Kg)	Position	A	B	C
55	180°	13.6 ± 4.1	13.1 ± 4	11.8 ± 3
55	90°	12.4 ± 4.6	18.3 ± 4.8	14.1 ± 4.6
55	0°	13.5 ± 6	11.4 ± 2.6	11.7 ± 2.9
100	180°	16.6 ± 7	16.9 ± 6.1	16.6 ± 5
100	90°	19.9 ± 5.8	25 ± 7	23.5 ± 7.1
100	0°	18.7 ± 7.3	19.5 ± 5	16.3 ± 5.6

Table 11. Table show mean (±SD) RMS values for right Erector Spinae (%MVC)

Weight (Kg)	Position	A	B	C
55	180°	11.4 ± 4.9	11.7 ± 7.2	11.2 ± 5.2
55	90°	11.5 ± 4.4	14.5 ± 6.9	13.8 ± 5.5
55	0°	11 ± 5.2	10.2 ± 5.7	11.8 ± 4.3
100	180°	12.6 ± 4.1	13.6 ± 4.8	14.2 ± 4.9
100	90°	13.5 ± 5.5	14.1 ± 6.5	15 ± 4.7
100	0°	13.8 ± 5.5	12.8 ± 5.2	13.4 ± 5.2

Table 12. Table show mean (±SD) RMS values for left Erector Spinae (%MVC)

Weight (Kg)	Position	A	B	C
55	180°	11 ± 4.2	12.8 ± 3.1	11.5 ± 4.0
55	90°	10.9 ± 2.8	12.6 ± 2	12.9 ± 2
55	0°	11.8 ± 3	10.2 ± 2.6	12.5 ± 3.2
100	180°	10.1 ± 4.5	11.5 ± 3.8	12.5 ± 4.8
100	90°	12.4 ± 3.5	14.7 ± 4.7	15.8 ± 4.7
100	0°	10.4 ± 4.2	10.4 ± 5.0	12.5 ± 4.3

As for peak values, RMS values showed no statistically significant differences. It is possible to notice, however, the same trends observed for mean peak values.

A WhCh showed the lowest RMS values pushing 55 kg with the steering wheels at 90° and pushing 100 kg with the steering wheels at 180° and 90°.

4 Conclusions

Sustained forces were all within the limit of 5 kg for pushing wheelchairs every 30 min. Clear statistical differences were found between A WhCh with respect to B and C pushing 55 kg and between B WhCh with respect to A and C pushing 100 kg (Table 3).

For initial forces, B WhCh, with a passenger of 100 kg, exceeded the safety limits in the case of wheel starting position of 90° to the direction of travel, whilst we are close to the limit with the front wheels in the direction of travel or at 180° to the direction of travel. With a passenger of 55 kg, however, even with the C WhCh, we do not exceed the 14 kg limit with the wheels in a starting position of 90° to the direction of travel. However, with the wheels in line with or at 180° to the direction of travel, the B WhCh is well within the recommended limits for a passenger of 55 kg. With the C WhCh, however, for a passenger of 100 kg, we go beyond the safety limits with the wheels in a starting position of 90° to the direction of travel, whilst we only just exceed the limits with the wheels in a starting position of 180° to the direction of travel. However, for a passenger of 55 kg, we are always within the safety limits with the C WhCh. Initial forces showed a strong statistical significance between A WhCh with respect to B and C in all the investigated configurations except that for A WhCh versus B WhCh pushing 100 kg at 0°. Poor statistical significance was found in initial forces between WhCh B and C.

Surface electromyography showed no statistical differences in the investigated parameters in all investigated muscles. In spite of that it is possible to observe some characteristic trends. For both sEMG parameters (peak and RMS) and for all the investigated muscles. A WhCh, despite its greater weight (Table 1), showed the lowest values in the most demanding configurations (pushing 100 kg with the steering wheels at 180° and 90° and pushing 55 kg with the steering wheels at 90°). The poor statistical differences could be due to the restricted number of subjects and other technical features, as handle width, that could involve other muscles not taken into account.

Future researches are needed, with a larger sample, to confirm these trends and going to investigate other upper limb agonist/antagonist muscles so as to check also their coactivation.

In light of these considerations, we can conclude that:

- A WhCh can be used safely with passengers of 55 kg to 100 kg, regardless of the wheel starting position in relation to the direction of travel.
- B WhCh can be used safely with passengers of 55 kg to 100 kg, ensuring that the wheel starting position is in line with the direction of travel or, at worst, at 180° to the direction of travel, because with the wheels in a starting position of 90° to the direction of travel, the initial force could exceed the safety limits.
- C WhCh should be reserved for transporting lighter passengers, taking care to position the wheels before departure in the direction of travel or, at worst, at 180° to the direction of travel, because with the wheels in a starting position of 90° to the direction of travel, the initial force could get very close to or exceed the safety limits.

References

1. Garg, A., Waters, T., Kapellusch, J., Karwowski, W.: Psychophysical basis for maximum pushing and pulling forces: a review and recommendations. Int. J. Ind. Ergon. **44**(2), 281–291 (2014)
2. Miller, J.: The ergonomics of in-flight service on aircraft in Australian domestic airlines. In: Proceedings of the 22nd Annual Conference of the Ergonomics Society of Australia and New Zealand, Australia, pp. 45–52 (1985)
3. Eastman Kodak Co. Ergonomic Design for People at Work, vol. 2. Van Nostrand Reinhold, New York (1986)
4. Lawson, J., Potiki, J., Watson, H.: Development of ergonomics guidelines for manually handled trolleys in the health industry. J Occup. Health Saf. Aust. New Zeal. **9**(5), 459–465 (1993)
5. Al-Eisawi, K.W., Kerk, C.J., Gongleton, J.J., Amendola, A.A., Jenkins, O.C., Gains, W.G.: Factors affecting minimum push and pull forces of manual carts. Appl. Ergon. **30**(3), 235–245 (1999)
6. Das, B., Wimpee, J., Das, B.: Ergonomics evaluation and redesign of a hospital meal cart. Appl. Ergon. **33**(4), 309–318 (2002)
7. Laursen, B., Schibye, B.: The effect of different surfaces on biomechanical loading of shoulder and lumbar spine during pushing and pulling of two-wheeled containers. Appl. Ergon. **33**, 167–174 (2002)
8. Drury, C.G., Barnes, RE., Daniels, E.B.: Pedestrian operated vehicles in hospitals. In: Proceedings of the 26th Spring Annual Conference and World Productivity Congress, Norcross, GA. American Institute of Industrial Engineers, pp. 184–191 (1975)
9. David, G.C., Nicholson, A.S.: The Safety Practitioner. Institution of Occupational Safety and Health, Leicester, UK, Aids to lifting and handling, pp. 4–7, July 1985
10. Konz, S., Johnson, S.: Work Design: Industrial Ergonomics. Sixth. Holcomb Hathaway, Arizona (2004)
11. Al-Eisawi, K.W., Kerk, C.J., Gongleton, J.J., Amendola, A.A., Jenkins, O.C., Gains, W.G.: The effect of handle height and cart load on the initial hand forces in cart pushing and pulling. Ergonomics. **42**(8), 1099–1113 (1999b)
12. International Organization for Standardization (ISO). Ergonomics – manual handling – part 2: Pushing and pulling. Geneva: ISO 2007. Standard No. ISO 11228-2 2007
13. Barbero, M., Merletti, R., Rainoldi, A.: Atlas of Muscle Innervation Zones: Understanding Surface Electromyography and its Applications. Springer, Mailand(2012)
14. Hermens, H.J., Freriks, B., Merletti, R., et al.: European recommendations for surface ElectroMyoGraphy (SENIAM) (2000)
15. Snook, S.H., Ciriello, V.M.: The design of manual handling tasks: revised tables of maximum acceptable weights and forces. Ergonomics **34**, 1197–1213 (1991)

Ergonomic and Anthropometric Preliminary Study to Determine Whether Moving a Loaded Cart Can Cause Musculoskeletal Disorders

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Abstract. A specialized risk estimation and evaluation was carried out to determine if moving a loaded cart could cause musculoskeletal disorders. The implemented methodology for determining the risk consisted of: (a) anthropometric study of 380 male workers for establishing they age and stature. (b) Measuring sustained push force. (c) Determination of synthetic distributions of strength at selected relative handle height. (d) Estimation of basic force limits and compressive strength limits for the target population. The workers' characteristics resulted from the anthropometric study were age < 20 9.5%, 20 < age < 50 86.81% and age > 50 3.69%. The synthetic distribution of strength for pushing activities, considered the following assumptions: absolute handle height of 1.1 m, and the fifteenth percentile as basic force limits. The result of 259 N is smaller 310 N precalculated force limits in tables; the risk was determined as not acceptable. Therefore, it is necessary consider the demographic characteristics of the population when a risk is evaluated.

Keywords: Ergonomics · Risk evaluation · Anthropometrics

1 Introduction

When a push task is evaluated, the information needed consist of anthropometric information about the workers' age and stature and detailed information as exact forces applied when they performing the activity. The anthropometry uses special terms and procedures to describe the characteristics of the user population in statistical terms [1] and determine the constraints upon the task design. On the other hand, strength is dependent on posture, for reasons of physiology and mechanics. According to ISO 11228-2 pushing is "*human physical effort where the motive force is directed to the front of, and away from, the*

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operator's body as the operator stands or moves forward" [2]. If the sustained force to accelerate the object is repeated continuously, and the basic force limited is exceeded, then it can cause back pain. The manual material handing activities such as lifting, carrying, pushing, and pulling are considering as cause of musculoskeletal disorders (MSD) [3] if the range of motion, the neuromuscular strength and the flexibility of the workers are over exposed. The current study, exemplify a specialized risk estimation and evaluation to determine if moving a loaded cart could cause musculoskeletal disorders. An anthropometric study developed for male workers to establish age and stature, to determine a synthetic strength distribution of the sustained push force were used. Finally, in order to determine the risk level, a comparison between the basic force limit obtained from the target population and the precalculated force limits in standard ISO 11228-2 tables was made.

2 Study Case

The task consisted of push carts loaded with plastics rolls from warehouse to production area (see Fig. 1). The travel distance was 30 m on average; the task frequency was 12 times per shift of 12 h. Each roll weight approximately 90 kg and the worker moved five rolls at the same time summarized around 450 kg. Each cart was made of stainless steel and weighted 75 kg. Two hands applied the forces all the movement and changed of directions of movement occurred almost three times during the material translation. In hot environmental the task was developed, it imposed additional hazards on the worker. There were no slopes and ramps on the way. Regarding Individual characteristics, all the workers that performed the task were male.

Fig. 1. Example of plastic rolls that was manipulated by workers during the push and pull task.

3 Methodology for Specialized Risk Estimation and Evaluation

The risk assessment procedure used in the present work is known as "Method 2 specialized risk estimation and evaluation" [2]. It determines force limits according to specific characteristics of the target group. Even though the method 1 - generalized risk estimation and risk evaluation, provides a simple risk assessment checklist and psychophysical tables, it is considered not applicable due to the population is not addressable by the psychophysical tables. That consideration was done due to the Snook and Ciriello tables contained in the standard ISO 11228-2 were performed with data of workers from industrial locations in the United States, then the anthropometric data population from that study is relatively different to Mexican anthropometric data.

3.1 Anthropometric Study

The anthropometric study presented in this investigation utilize age, stature and force variables from a previous study done with male workers, from different companies in Morelos State, Mexico; the previous study was based in [4–6] recommendations. In order to set up a target group for this investigation, data from 380 workers who have developed pushing and pulling tasks were selected; all ages and statures were included.

3.1.1 Mean, Standard Deviation and Relative Frequency

In order to establish the statistical data, only consider male adults. The objective was determining the relative frequency of different ages and statures. Using Eqs. (1), (2) and (3) the estimation of the mean, the standard deviation and the relative frequency were determined. The ungrouped frequency distribution of stature is given in Table 1.

$$\sum \mathrm{x/n} = \mathrm{m}. \tag{1}$$

$$\sqrt{\left(\sum (\mathrm{x} - \mathrm{m})^2/\mathrm{n}\right)} = \mathrm{s}. \tag{2}$$

$$\mathrm{fi/n} = \mathrm{rf}. \tag{3}$$

The variable *x* represents the age or stature of each worker, *n* is the sample size of 380 men, *m* is the estimated mean and *s* is the sample standard deviation.

Table 1. Ungrouped frequency distribution of stature of male workers.

Stature cm	f	rf	Stature cm	f	rf	Stature cm	f	rf
155	8	1.84	165	18	4.74	175	11	2.89
156	15	3.95	166	23	6.05	176	14	3.68
157	7	1.58	167	17	4.47	177	7	1.58
158	9	2.37	168	12	2.89	178	10	2.63
159	12	3.16	169	29	7.37	180	4	1.05
160	14	3.68	170	25	6.32	181	6	1.58
161	11	2.89	171	21	5.53	184	4	1.05
162	16	4.21	172	19	5.00	187	5	0.26
163	13	3.42	173	13	3.42	188	2	1.05
164	22	5.53	174	13	3.42			

3.1.2 Graphic Representation

Histogram was used in order to develop a graphic representation, in which stature probability (frequency of encounter) is plotted (see Fig. 2).

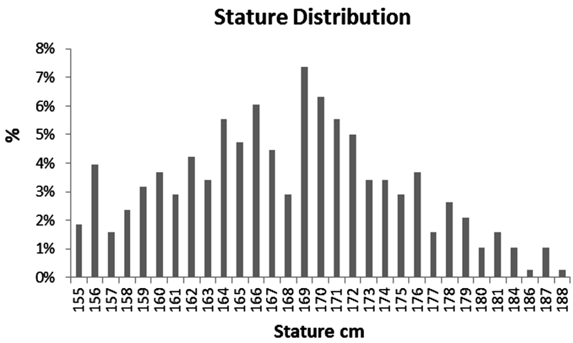

Fig. 2. Stature frequency distribution of 380 workers who have developed pushing task and pulling tasks.

The relative frequency was organized by age as follow: group 1 - population clusters in age < 20 years; group 2 - population clusters in age 20 years < age < 50 years and group 3 - population clusters in age > 50 years (see Fig. 3).

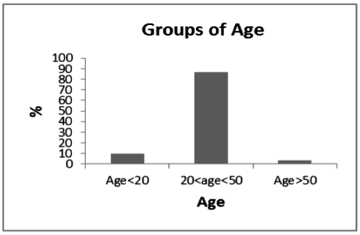

Fig. 3. Frequency distribution of three groups of age.

3.2 Procedure to Estimate the Synthetic Distribution of Strength

3.2.1 Collecting Input Data

In the first place, measuring of sustained push force was found experimentally according to annex D [2]. During collecting input data the absolute handle height, h_{abs} was established in 1.1 m, and target group characteristics were determined with the anthropometric study described above. Secondly, the synthetic distribution of strength was estimated as follow:

$$\bar{F} \cdot \alpha_i = F_i. \tag{4}$$

$$\sigma \cdot s_i = \sigma_i. \tag{5}$$

The variable $\bar{F}$ represents the strength average of experimental data. i are the age groups, F_i and σ_i represents the force average and the standard deviation for each relation strength-stature, α_i and s_i represents subgroup multipliers synthesizing subgroup strength distributions (provided by annex F) [2], where α_1 = 1.95 for group 1 and α_2 = 2.16 for group 2, s_1 = 1.57 and s_2 = 1.65.

3.2.2 Determining Muscle Force Limits

In order to determine the Basic force limits, F_B was found by taking a percentile approach as described in EN 1005-3 [7], which establishes that the strength limits, can be determined by calculating the 15th percentile. The equations used for determining it are the following:

$$\mathrm{Ln}(\bar{F}_i) = \bar{F}_i. \tag{6}$$

$$\mathrm{Ln}[(\bar{F}_i + \sigma_i)/\bar{F}_i] = \sigma_i. \tag{7}$$

$$e^{\ln F2} = F\% \tag{8}$$

It is recommendable uses the limit force 15th percentile for professional users from adult with age between 20 to 65 years [7]. The limits established by the proposed procedure have the objective to reduce the risks to at least 85% of the potential population users. Therefore, it corresponding to strength represented by the 15% of F_B defined in Table 2 and Fig. 4, as F% = $e^{\ln F2}$.

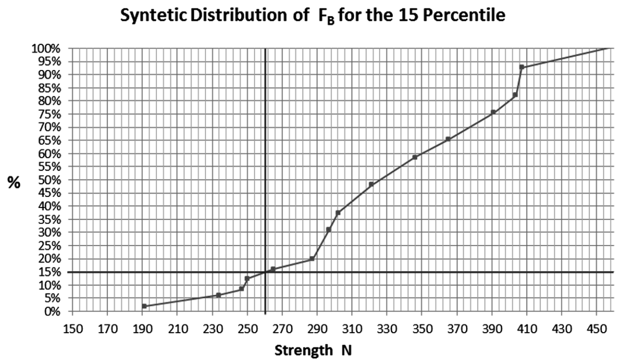

Fig. 4. Graphic representation of synthetic distribution of basic force limit for 15th percentile.

Table 2. Synthetic frequency distribution of strength for group 2.

Ln $\bar{F}_2$ N	rf %	Crf %	Lnσ_i	F% = $e^{\ln F\%}$ N	15^{th} %ile N
5.399	1.8	1.8	0.139	221	191
5.577	4.2	6.1	0.118	264	234
5.626	2.4	8.4	0.112	278	247
5.638	3.9	12.4	0.111	281	250
5.691	3.7	16.1	0.106	296	265
5.764	3.7	19.8	0.099	319	287
5.793	9.6	31.1	0.096	328	297
5.809	6.3	37.4	0.094	333	302
5.866	10.8	48.2	0.089	353	321
5.934	10.3	58.5	0.084	378	346
5.983	6.8	65.3	0.080	397	365
6.047	10.3	75.6	0.075	423	391
6.077	6.6	82.2	0.073	436	404
6.085	10.5	91.0	0.072	439	407
6.212	9.0	100.0	0.064	499	466

The value F_B resulted was 259 N and it is considered as target group basic force limit (see Fig. 4.) It is assumed that a 15% of the target group could be affected, due to it exceeds their muscle-strength force limits.

3.3 Risk Estimation and Evaluation

3.3.1 Adjustments to Basic Force Limits F_{Br}

The procedure established for determining the muscle-based force limits F_{Br}, determines that is necessary adjusting the basic force limits F_B, according to the distance d, and frequency f of the pushing task. Using the following equation:

$$F_B[1 - m_d(d) - m_f(f)] = F_{BR}. \tag{9}$$

F_{Br} represents the adjustments to basic force limits, F_B represents the basic force limit, m_d represents the travel distance multiplier, m_f represents the task frequency multiplier, f represents the frequency the task is repeated over the course of a working day (in number of times per minute), d represents the travel distance (in meters) of the pushing task.

3.3.2 Skeletal-Strength-Based Force Limits F_C and F_{LS}

Taking into account the age of the target group, assessing the action force was done through the estimation of compressive force limits of lumbar spine F_C, choosing it

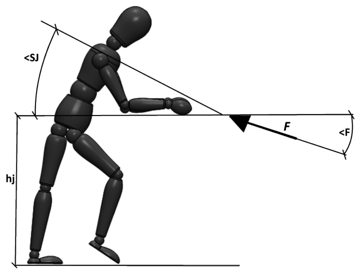

Fig. 5. Representation of the position pulling task, where ∠ SJ represents shoulder joint angle degrees, ∠ F represents the force angle degrees, hj represent the grip height m.

magnitude from tables, as well as, the identification of the action force limit F_{LS} was consulted by charts proposed by standard, in the Fig. 5 shows the variables needed for identifying them.

3.3.3 Limiting Force F_L and Safety Limit F_S

The procedure for estimating force and safety limit consisted of comparing F_{Br} vs F_{LS} considering:

$$\min(F_{BR}, F_{LS}) = F_L. \tag{10}$$

$$m_r \times F_L = F_S. \tag{11}$$

F_S represents the safety limit, it is calculated from the minimum limiting force, F_L, and a risk multiplier, m_r, where m_r = 0.85 represents green zone; m_r = 1.0 represents yellow zone. Finally a comparison between actual forces respects to F_S for the final evaluation is given in Table 3.

Table 3. Final evaluation of forces

$\bar{F}$ N	Evaluation	$\bar{F}$ N	Evaluation
123	Green	185	Red
147	Green	196	Red
154	Green	210	Red
156	Green	235	Red
165	Yellow	242	Red
177	Yellow	244	Red
182	Yellow	277	Red

4 Evaluation Risk Results and Discussions

The stature distribution by relative frequency showed in Fig. 2 was representative of three groups; the range of data is large from 155 to 188 m. Thus, there is not a representative stature. As a result of that, the relative frequency of stature was small. For example, the most probable stature is 169 cm with 7.8% but this amount is not representative of the population. Consequently, the strength distribution was estimated for all statures. Moreover, age is an important factor in anthropometry as well as in risk evaluation; due the strength limit are different for each age group. The distribution organized by age and gender sowed in Fig. 3, established that group 2 had the bigger probability. Thus, that group was the target group selected.

The information from study case was used as input data for the risk estimation as follow: The strength represented by the 15% was consider as F_B with a estimation of 259 N, the travel distance was 30 m on average and the task frequency was 12 times per shift of 12 h, the absolute height was established in 1.1 m. The estimation of FBr obtained was:

$$259\,\mathrm{N}[1 - 0.38 - 0.09] = 183.89\ \mathrm{N} \tag{9}$$

In order to determine FLS magnitude from charts the following data was used: ∠ SJ was 20°, ∠ F was 0°, hj was 1.1 m, as is observed in Fig. 6.

Results from tables and charts:
FC = 3.9 kN active male adults 20–64 years
FLS = more than 600 N

The procedure for estimating force and safety limit consisted of comparing F_{Br} vs F_{LS} and choose the minimum magnitude, then F_{Br} = 183.89 N < F_{LS} = more than 600 N.

F_S for green zone = 156.31 N and F_S for yellow zone = 183.59 N.

As a result new groups of risk was generated considering the following data: Risk group 1 - population clusters in strength < 156.31 N; Risk group 2 - population clusters in strength 156.32 N < strength < 183.59 N and Risk group 3 - population clusters in strength > 183.59 N. The strength distribution organized by stature was analyzed concluded that for the pushing task established in the study case causes musculoskeletal disorders (see Fig. 7).

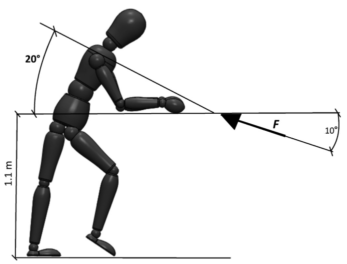

Fig. 6. Representation of the position pulling task ∠ SJ = 20°, ∠ F = 10°, hj = 1.1 m

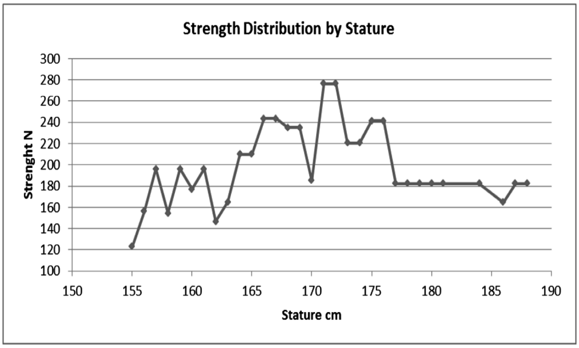

Fig. 7. Graphical representation of strength distribution organized by stature

5 Conclusions

A specialized risk estimation and evaluation carried out to determine if moving a loaded cart could cause musculoskeletal disorders. The Method 2 specialized risk estimation and evaluation proposed by ISO11228-2 was implemented considering anthropometric data of 380 male workers. Estimation of basic force limits and compressive strength limits for the target population was 256 N for pushing activities, considering the following assumptions: absolute handle height of 1.1 m, and the fifteenth percentile as basic force limits. The result of 256 N not exceeded the 310 N precalculated force limits in tables. Thus, the risk evaluation was determined as not acceptable. The strength distribution organized by stature was analyzed concluded that for the pushing task established in the study case causes musculoskeletal disorders.

References

1. Karwowski, W. (Ed.): International Encyclopedia of Ergonomics and Human Factors, vol. 1. Taylor & Francis, Routledge (2001)
2. ISO 11228-2:2007 International Standard. Ergonomics – Manual Handling – Part 2: Pushing and Pulling. First Edition (2007)
3. Gatchel, R.J., Schultz, I.Z. (Eds.): Handbook of Musculoskeletal Pain and Disability Disorders in the Workplace. Springer (2014)
4. Pheasant, S.: Body Space, Anthropometry, Ergonomics and the Design Work, Second Edition. Taylor & Francys, Routledge (2003)
5. ISO 7250-1: 2008 International Standard. Basic human body measurements for technological design – Part 1: Body measurement definitions and landmarks (2008)
6. National Health and Nutrition Examination Survey (NHANES). National Youth Fitness Survey (NYFS) Body Measures Procedure Manual (2012). https://www.cdc.gov/nchs/data/nnyfs/body_measures.pdf
7. UNE - EN 1005-3 Norma Española, Seguridad de las máquinas, comportamiento físico del ser humano. Parte 3: Límites de fuerza recomendados para la utilización de máquinas (2002)

The Blessings and Curses of Job Stress: Exploring the Job Stress – OCB/CWB Nexus Among Ghanaian Bankers

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Abstract. There have been mixed and inconclusive findings about the relationship between job stress and voluntary behaviour universally. Drawing from the social exchange and conservation resource theories, this study examines the relationship between job stress and the organizational citizenship behaviour, OCB and counterproductive work behaviour, CWB among Ghanaian bankers. A sample of 363 Ghanaian bankers from 18 commercial banks in Ghana were used for the study. The study found a significant negative relationship between job stress and the citizenship behaviour of the bankers. Though a cause and effect relationship was found between job stress and unproductive behaviours, the relationship was negative. The study explained this finding on the basis of more Millennials entering today's work environment. This study is the first to examine the job stress – voluntary behaviour nexus in the Ghanaian banking sector and thus has practical implications for the sector.

Keywords: Job stress · Voluntary work behaviour
Organizational citizenship behaviour · Counterproductive work behaviour
Bank

1 Introduction

The banking industry the world over has proven to be among the resilient industries and among the thriving sectors of the economy. In Ghana, the banking sector is one of the fastest growing and highly competitive industries with the recent increase in local and foreign banks entering the sector [1]. As a result of this competition, banks are restructuring their activities, operational hours and days and other products and services in order to remain not only in business but also gain a greater competitive advantage in the industry. These responses to the dynamics and competition in the industry are apparently stressing more employees than ever before.

Of significant interest of the issue of stress in the banking sector, however, is its effect on organizational citizenship behaviour (OCB) and counterproductive work behaviour (CWB) popularly known as voluntary work behaviours [2]. A number of

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studies have established significant relationships between job stress and voluntary behaviours [3–7]. The concepts of OCB and CWB are critical employee behaviours due to the prevalence and the respective "blessings and curses" these concepts bring to an organization. OCBs are highly preferable organizational behaviours. For CWB, Penny and Spector [8] has shown that about 95% of all employees at some point in their career engage in CWB. A previous study by Govoni [9] also revealed that employee theft, an aspect of CWB, had a relative cost of about 200 billion US Dollars to businesses in the United States of America. These evidences underscore the relevance of voluntary work behaviours in the success or failure of firms.

Though studies on the relationship between job and OCB and CWB are increasingly gaining attention among researchers, such findings have been mixed. While some researchers [see 3, 4] have reported negative relationships between job stress and OCB, studies like that of Paillé [10] and Ayatse and Ikyanyon [11] found no relationship between the two concepts. Again, as studies of P. Chand and P.K. Chand [5], Roxana [6] and Aftab and Javeed [7] all found positive relationships between job stress and CWB, Tucker and his colleagues [12] reported a somewhat negative relationship between work demands related job stress and CWB.

Furthermore, even though literature on job stress in the Ghanaian banking sector seems to be gaining prominence [13–15] the job stress – voluntary behaviour nexus has apparently received little attention in the same context. Most studies that have examined the relationship between job stress and OCB or CWB have mainly been in developed regions.

Given the changing trends in the banking sector inducing stress among workers and the peculiarity of voluntary work behaviours to contexts, this study seeks to examine the relationship between job stress and OCB and CWB in the Ghanaian banking sector. This study is opportune considering the fast pace of entry of new banks, increasing competition in the banking industry and thereby causing stress among employees.

2 Theoretical Underpinning and Hypotheses Development

2.1 Job Stress

According to Huseyin and Mustafa [16], stress is a physiological and psychological reaction that happens when an individual either fulfils or changes a threat or challenge to a tenser situation. Sulsky and Smith [17] opine that job stress occur as a result of the interaction that happens between stimulation from the environment (pressure) and individual's reaction (which is mostly quite strained). Job stress could therefore be described as an adaptation reaction, due to individual differences or psychological processes that comes from a situation from the outside, or events that put on a lot of physical and psychological strain on an individual. Job stress can occur as a result of unconditional working hours, loud noise, boring scope of work, inability to socialize well, vagueness in the role and responsibility of decision making without sufficient or minimal autonomy Job stress has a wide range of effects on the individual as well as on the organization. In this study, it is argued that job stress will affect the citizenship and counterproductive work behaviours of employees.

2.2 Voluntary Work Behaviour

The term voluntary work behaviour was used by Coyne and Gentile [2] when they developed a scale that concurrently measured OCB and CWB. Arguments, however, about the relationship between the two constructs, OCB and CWB are rife, and that will be discussed later in this section.

Organizational citizenship behaviour is defined by Organ [18] as "individual behaviour that is discretionary, not directly or explicitly recognized by the formal reward system, and that in the aggregate promotes the effective functioning of the organization" (p. 4). OCB behaviours include helping behaviours towards co-workers [19], impersonal contributions to an organization, preventing other workers from falling into problems [18], tolerating "inconveniences and impositions accruing from the job without complaints or excessive demands for relief or redress" [20, p. 255] and total commitment and involvement in the issues of the organization.

Counterproductive work behaviour generally refers to behaviours that are harmful to the legitimate interest of an organization by hurting employees in ways that reduce their effectiveness or directly affecting the functioning and properties of the organization [21]. They include behaviours such as theft, taking long breaks during working hours, absenteeism, overbilling an organization through presenteeism, showing aggressive behaviours towards employees and destruction of company property.

The descriptions of the OCB and CWB constructs above may seem to offer some suggestion that there is a unidimensional opposite relationship between them. This assumption in recent times are being challenged due to studies contradicting the OCB-positive outcomes and CWB-negative outcomes findings in earlier studies. As much as the OCB-CWB nexus does not constitute one of the aims of this study, it is important to note that the consideration of OCB and CWB as multi-dimensionally distinct rather than unidimensional opposite constructs is more favored in extant literature [see 22, 23].

2.3 Review of Theories

The social exchange theory and conservation of resources theory explain the jobs stress – OCB/CWB nexus. The social exchange theory explains how organizations and employees exchange socioemotional benefits [24]. Research suggests that when employees receive valuable and fairly administered benefits from their organization, they form social exchange relationships and in turn engage in improved performance, increased OCBs and less intentions to quit their jobs [3, 25]. However, stress inhibits the administration of valued benefits considered as fair by employees, thus reducing their will and ability to form such social exchange relationships with the organization. This view is supported by researchers such as [3, 4] who found negative relationships between job stress and OCB. It is thus expected in this study that the influence job stress will have on OCB will be negative. This study thus hypothesizes that:

> *H_1: There will be a negative cause and effect relationship between job stress and the citizenship behaviour of bankers in Ghana*

Again, the conservation of resources theory [26] assumes that under stressful conditions, people tend to be more determined to protect and retain resources. In its relation to CWB, Gallagher, Haris and Valle [27] explains that there are certain behaviours that are of interest to individuals and they would do everything to protect such behaviours even in spite of stressful circumstances. Hence, since individuals would not like to lose some behaviours in their personality, they readily engage in CWB as part of this protective mechanism [12, 27]. This means that under increased stress, individuals are more likely to engage in unproductive and deviant behaviours. Some studies, for example [5–7] have provided empirical support for the positive relationship between job stress and CWB. It is therefore hypothesized in this study that:

H_2: There will be a positive cause and effect relationship between job stress and the counterproductive work behaviour of bankers in Ghana

3 Method

3.1 Participants and Procedures

The study was conducted as cross-sectional survey of bankers. Questionnaires were administrated online via the e-mail of bankers and a total of 363 bankers responded fully to all the items in the questionnaire. The online questionnaire administration approach was adopted due to the busy schedules of bankers and the high level of job concentration required of them during their working hours. This approach allowed them to answer the questions at their off-working hours and also helped the researcher to reach to an appropriate number of sample for this study.

Currently, there are 35 licensed commercial banks in Ghana [28]. Due to the difficulty in accessing personal data of employees in especially the newly licensed banks (7 of them were licensed since 2016), and some other banks, data was retrieved from 18 of the 35 licensed banks in Ghana (see Appendix A).

There was a fair representation of the sexes of the respondents used for this study (males = 54%, females = 46%). Majority of the respondents were relatively youthful. 48.2% of the respondents were between the ages of 31–40 and cumulatively, 89.8% were all 40 years and below. 52.6% of the respondents were married and 43.5% were single. 215 respondents representing 59.2% had worked in the banking sector for between 3 to 5 years. 78 of the respondents representing 21.5% had expended between 6 to 10 years in active service in the bank. Also, majority of the respondents (49.9%) had at least a Diploma or Higher National Diplomas as their highest educational qualification as at the time this study was being conducted.

3.2 Measures

Job Stress. To measure job stress, Parker and Decotiis' [29] jobs stress scale was adopted. 12 items of job stress were measured on a 5 point Likert type scale where 1 = "strong agreement", 2 = "agreement", 3 = "indifferent", 4 = "disagreement", 5 = "strong disagreement". One representative item was "I frequently get the feeling I am married to the company". The reliability of the scale was 0.964.

Organizational Citizenship Behaviour. Podsakoff, Mackenkezie, Moorman and Fetter's [19] scale was adopted to measure OCB. The scale describes five dimensions including altruism, conscientiousness, sportsmanship, courtesy and civic virtue using 24 items on a 5-point Likert-type scale where 1 = "never", 2 = "disagree", 3 = "neutral", 4 = "agree", 5 = "always". A representative sample item included "I help other who have been absent, I willingly help others who have work-related problems." The reliability of the scale was 0.93.

Counterproductive Work Behaviour. To measure counterproductive work behaviour, Aquino, Lewis and Bradfield's [30] deviant behaviour scale was adopted. 19 items were measured on a 5-point Likert-type scale where 1 = "never", 2 = "disagree", 3 = "neutral", 4 = "agree", 5 = "always". A representative item in the scale was "I made an ethnic, racial or religious comment against a co-worker". The reliability for this scale was 0.831.

4 Results

The descriptive statistics and correlations of the variables in this study were calculated and their means and standard deviations are reported below.

Table 1. Descriptive statistics and correlation matrix

		Mean	SD	1	2	3
1	Job stress	1.5083	.67198	1		
2	Organizational citizenship behaviour	4.1405	.63379	–.242**	1	
3	Counterproductive work behaviour	2.1512	.48004	–.174**	.004	1

** Correlation is significant at the 0.01 level (2-tailed)

From Table 1 above, results from a sample of 363 bankers showed a mean score for job stress of 1.5083 with standard deviation of 0.67198. Also, the mean and standard deviation for citizenship behavior were 4.1405 and 0.63379 respectively. The mean score for counterproductive work behavior was 2.1512 and standard deviation for same was 0.48004.

4.1 Hypothesis 1

H_1: There will be a negative cause and effect relationship between job stress and the citizenship behaviour of bankers in Ghana. This hypothesis was tested using simple linear regression. The results are shown below.

Table 2 shows that the regression model for that influence the relationship of job stress on OCB was significantly fit ($F = 22.520$, $p < .001$). R square of 0.059 indicates that job stress accounts for approximately 5.9% of the variation in citizenship behaviour among bankers. The results show that there is a significant negative relationship between job stress and organizational citizenship behaviour ($\beta = -0.242$, $p < .000$). The results thus supports the hypothesis that there is a negative cause and effect relationship between job stress and the citizenship behaviour of Ghanaian bankers.

Table 2. Results of simple regression for job stress on OCB

	B	Std. error	Beta
Intercept	4.485	0.080	
Job stress	–0.229	0.048	–0.242**

Note: $R^2 = 0.059$, $F = 22.520$, **$p < .001$

4.2 Hypothesis 2

H_2: There will be a positive cause and effect relationship between job stress and the counterproductive work behaviour of bankers in Ghana. This hypothesis was also tested using simple linear regression. The results are presented below.

Table 3 shows that the regression model for that influence the relationship of job stress on CWB was significantly fit ($F = 11.325$, $p < .001$). R square of 0.030 shows that job stress accounts for approximately 3% of the variation in counterproductive work behaviour among bankers. The results also show there is a significant negative relationship between job stress and counterproductive work behaviour ($\beta = -0.174$, $p < .001$). The results only partially supports the hypothesis that there is a positive cause and effect relationship between job stress and the citizenship behaviour of Ghanaian bankers. The results show that though there is a cause and effect relationship between job stress and CWB, this relationship is negative.

Table 3. Results of simple regression for job stress on CWB

	B	Std. error	Beta
Intercept	2.339	0.061	
Job stress	–0.125	0.037	–0.174**

Note: $R^2 = 0.030$, $F = 11.325$, **$p < .001$

5 Discussion

Drawing from the social exchange and conservation resource theories, this study aimed to examine the relationship between job stress and the voluntary behaviours (OCB and CWB) of Ghanaian bankers. The study found a significant negative relationship between job stress and the citizenship behaviour of the bankers. This means that as employees increasingly perceive their work gives them no room for their personal life due to work overload. This finding is first supported by the social exchange theory and other previous researchers [3, 4]. According to the social exchange theory, when employees receive valuable and fairly administered benefits from their organization, they form social exchange relationships and in turn engage in improved performance [24]. The absence of a favourable working condition as a result of job stress will thus limit the employee's desire to exchange helping behaviours with the organization [3, 25]. Jain and Cooper [3] examined the direct effect of stress on OCB and found a significant negative impact in the relationship. A more related study by Karabay [4] in the banking industry also examined the relationship between employees' work stress, organizational commitment and some sub-dimensions of organizational citizenship behaviour (courtesy and consciousness) and found a negative relationship between the work stress of Turkish bankers and their citizenship behaviour. These studies thus supported the hypothesis developed for this research.

Also, the study found a significant negative relationship between job stress and unproductive behaviours among bankers in Ghana. This finding is quite interesting as it suggests that as job stress increases the tendency of the bankers to engage in deviant behaviours is likely to reduce. In other words, as employees perceive their work as putting so much pressure on them such that they hardly find time for their personal life, the employees will rather have less interest in being unproductive and rude to their co-workers or supervisors. This finding contradicts the conservation resource theory and findings of past studies that have reported a positive relationship between stress and counterproductive work behaviour. The conservation of resources theory [26] holds the assumption that under stressful conditions, people tend to be more determined to protect and retain resources and that there are certain behaviours that are of interest to individuals and they would do everything to protect such behaviours even in spite of stressful circumstances. Hence, since individuals would not like to lose some behaviours in their personality, they readily engage in CWB as part of this protective mechanism [27]. This means that under increased stress, individuals are more likely to engage in unproductive and deviant behaviours. However, the findings of this current study did not support the theory.

A critical examination of the bio-data of the respondents may provide some explanation for this new finding with respect to the negative relationship between job stress and counterproductive work behaviour. Majority of the respondents (about 90%) were below the age of 40 years old and thus could be classified as Millennials, that is those born from 1982 to 1999 [31]. Research has shown some peculiar characteristics of these Millennials, describing them as different from previous generations in terms of what they value at work and their attitudes. According to Twenge, Campbell, Hoffman and Lance [32], Millennials unlike previous generations are driven by extrinsic rather than intrinsic motivation. This means that monetary payments and financial rewards are highly desirable to Millennials. The banking industry in Ghana is among the highest paying sectors of the Ghanaian economy. This is likely to make the sector more attractive to Millennials. It was however not surprising the number of younger population that were found in this study. But more importantly, the high salaries and financial benefits and allowances that these Millennials receive form their respective banks in some way explains why even when they report high stress levels, they are more likely to report a low tendency to engage in deviant behaviours. This is because monetary rewards could neutralize the consequence high stress in the banking sector. Besides, there is high youth unemployment in Ghana [33]. Therefore, for those who have had the opportunity to enter the high paying banking industry, as much as they would like to honestly report on the high stress levels in the sector, may be hesitant to allow it to influence their unproductive behaviours least they are laid off to join the unemployment train.

Other explanations are that, researchers have found that aside the demands of the job, factors such as personality traits of individuals [34] and organizational justice [35] may cause people to engage in deviant behaviours. Some employees may engage in counterproductive work behaviours even when their job demands do not stress them but just because they are personally disposed to such deviant behaviours. Again, most banks are now employing individuals based on short-term contracts through various employment agencies. However, such contract staff often have a poor perception of organizational justice since they are often excluded from some benefits and allowances enjoyed by full-time/permanent staff. This may thus be a motivator for them to engage in deviant behaviours even when their work does not necessarily stress them.

The findings of this study has some practical implications for the banking sector as well as recommendations for future studies.

6 Practical Implications

This study is highly informative for practitioners and managers in the Ghanaian banking sector. Previous studies on job stress in the Ghanaian banking industry have provided some knowledge about the nature and causes of job stress in organizations [13, 14]. Though these findings are relevant for the banking sector, they seem to only describe the obvious, that is, there is job stress in a highly competitive industry such as the banking sector in Ghana. The absence of sufficient knowledge on the consequence of job stress in the sector may lead to situations where job stress could be considered as an integral aspect of the banking job and thus left as an "occupational hazard".

This study is therefore significant in the sense that it offers bankers and their management sufficient knowledge about the impact of stress in the bank on the behaviour of employees. More critically, managers must understand that job stress in itself is not costly to their organizations. It is rather its consequences that can be costly. Managers must therefore create conditions in their workplaces that increases citizenship behaviours and at the same time reduces stress. One way to enhance citizenship behaviour of employees as shown in this study is to reduce job stress.

Firms should consider reducing the workload of their staff. This will them to form social exchange relationships with the organization and reward the firm with extra-role performances and tolerate inconveniences at work. Also, firms could offer flexible work schedules with employees as a way of compensating them for the extensive use of their work and personal life time.

Again, considering the entry of more Millennials into the job scene, firms must encourage them by offering pay mixes that offers more financial reward to employees as compared to personal growth and development rewards. This is because newer generations as shown previously are motivated by extrinsic rewards and these rewards when present is likely to neutralize their tendency to engage in deviant behaviours at the workplace. This stems from the fact that finding a job especially in Ghana and some parts of Africa is a daunting task and any job that offers high reward will be considered as a treasure by Millennials.

7 Limitations and Recommendations for Future Research

This study used the cross-sectional approach and according to Volgesgang, Leroy and Avolio [36], this approach is likely to result in a common method bias or source bias. In order to address these biases, future studies should collect data from respondents at two separate times at an interval that will ensure that responses are not characterized by bias.

Furthermore, the relationship between job stress and voluntary behaviours were examined directly. This resulted in job stress explaining only a minute aspect of the variation in OCB and CWB. Factors such as organizational climate, job satisfaction, organizational communication and recognition have been found to moderate and mediate the job stress – OCB/CWB nexus. It is thus recommended for future studies to examine the relationship between the variables in this study together with the mediating and moderating variables stated.

8 Conclusion

To conclude, it is imperative for organizations to pay critical attention to job stress due to the “blessings or curse” it could have on an organization. Also, as much as firms pay attention to other pressing organizational factors such as leadership that have significant influence on the productive and unproductive behaviours of employees, adequate attention must be paid to the working conditions including the load of work and availability of flexible schedules for employees. Besides, in a highly culturally and religious sensitive country like Ghana where extrinsic rewards for employees are often considered second to other relational rewards such as praise and motivation, there is the need for managers to revise their perception about the value financial rewards have for today’s employees. The current generation of organizational entrants value monetary rewards more than any other generation and organizations who realize this quick enough may reap benefits from it.

Appendix A

See (Table 4).

Table 4. List of study organizations

	Name of bank	Number of respondents	Percentage (%)
1	Prudential Bank	35	9.6
2	Ecobank Ghana Limited	25	6.9
3	CAL Bank	17	4.7
4	Zenith Bank	28	7.7
5	Barclays Bank	25	6.9
6	HFC Bank	15	4.1
7	Stanbic Bank	17	4.7
8	GCB Bank	21	5.8
9	Agricultural Development Bank	9	2.5
10	Fidelity Bank Limited	28	7.7
11	GN Bank	18	5.0
12	Sahel Sahara Bank	17	4.7
13	GT Bank	15	4.1
14	First Atlantic Bank	20	5.5
15	Standard Chartered Bank	25	6.9
16	Access Bank Ghana Limited	17	4.7
17	Royal Bank	16	4.4
18	UBA Bank	15	4.1
Total		363	100

References

1. Siddiqi, M.: Banking in Africa. Afr. Bus. **14**, 23–37 (2003)
2. Coyne, I., Gentile, D.: The Design and Development of a Voluntary Workplace Behaviour Scale. SHL group plc (2006)
3. Jain, A.K., Cooper, L.C.: Stress and organisational citizenship behaviours in Indian business process outsourcing organisations. IIMB Mgt. Rev. **24**, 155–163 (2012)
4. Karabay, M.E.: An investigation of the effects of work-related stress and organizational commitment on organizational citizenship behavior: a research on banking industry. J. Bus. Res. Turk **6**(1), 282–30 (2014)
5. Chand, P., Chand, P.K.: Job stressors as predictor of counterproductive work behaviour in indian banking sector. Int. J. App. Inn. Eng. Mgt. **3**(12), 43–55 (2014)
6. Roxana, A.: Antecedents and mediators of employees' counterproductive work behavior and intentions to quit. Proc. Soc. Beh. Sci. **84**, 219–224 (2013)
7. Aftab, H., Javeed, A.: The impact of job stress on the counter-productive work behavior (CWB): a case study from the financial sector of Pakistan. Int. J. Cont. Res. Bus. **4**(7), 590–604 (2012)

8. Penny, L.M., Spector, P.E.: Narcissism and counterproductive work behavior: do bigger egos mean bigger problems? Int. J. Sel. Ass. **10**, 126–134 (2002)
9. Govoni, S.J.: To Catch a Thief. CFO, 24–32 February 1992
10. Paillé, P.: Stressful work, citizenship behaviour and intention to leave the organization in a high turnover environment: examining the mediating role of job. J. Mgt. Res. **3**(1), 1–14 (2011)
11. Ayatse, F.A., Ikyanyon, D.N.: Organizational communication, job stress and citizenship behaviour of IT employees in Nigerian Universities. J. Bus. Admin. Res. **1**(1), 99–105 (2012)
12. Tucker, J.S., Sinclair, P.R., Mohr, C.D., Thomas, J.L., Salvi, A.D., Adler, A.B.: Stress and counterproductive work behavior: multiple relationships between demands, control, and soldier indiscipline over time. J. Occup. Health Psych. **14**(3), 257–271 (2009)
13. Asiseh, G.D.: Workload and Occupational Stress: The Moderating Role of Leadership Styles in Selected Banks in Ghana. Thesis Submitted to the University of Ghana, Legon in Partial Fulfilment of the Requirement for the Award of M. Phil. Human Resource Management (2016)
14. Gyan, C.: Stress and coping strategies among bankers in the tema metropolis. Dev. Ctry. Std. **4**(25), 34–41 (2014)
15. Dartey-Baah, K., Ampofo, E.Y.: Examining the influence of transformational and transactional leadership styles on perceived job stress among Ghanaian banking employees. Int. J. Bus. Mgt. **10**(8), 161–170 (2015)
16. Huseyin, A., Mustafa, T.: Nepotism, favoritism and cronyism: a study of their effects on job stress and job satisfaction in the banking industry of North Cyprus. Soc. Behav. Pers. Int. J. **36**(9), 1237–1250 (2008)
17. Sulsky, L., Smith, C.: Work Stress. Thomson Wadswort, Vicki Knight (2005)
18. Organ, D.W.: Organizational citizenship behaviour: it's construct clean-up time. Hum. Perform. **10**, 85–97 (1997)
19. Podsakoff, P.M., Mackenzie, S.B., Moorman, R.H., Fetter, R.: Transformational leader behaviours and their effects on followers' trust in leader, satisfaction organizational citizenship behaviour. Leadersh. Q. **1**(2), 107–142 (1990)
20. Konovsky, M.A., Organ, D.W.: Dispositional and contextual determinants of organizational citizenship behaviour. J. Organ. Behav. **17**(3), 253–266 (1996)
21. Fox, S., Spector, P.E., Miles, D.: Counterproductive work behavior (CWB) in response to job stressors and organizational justice: some mediator and moderator tests for autonomy and emotions. J. Vocat. Behav. **59**, 291–309 (2001)
22. Dalal, R.S., Lam, H., Weiss, H.M., Welch, E.R., Hulin, C.L.: A within-person approach to work behavior and performance: concurrent and lagged citizenship counter productivity associations and dynamic relationships with affect and overall job performance. Acad. Manag. Rev. **52**(5), 1051–1066 (2009)
23. Dartey-Baah, K., Arthur, R.: Leader integrity and employee outcomes: where do they collide? In: Kantola, J.I., Barath, T., Nazir, S., Andre, T. (eds.) Advances in Human Factors, Business Management, Training and Education, Advances in Intelligent Systems and Computing, 498. Springer, Cham (2017)
24. Blau, P.: Exchange and Power in Social Life. Wiley, New York (1964)
25. Wayne, S.J., Shore, L.M., Liden, R.C.: Perceived organizational support and leader member exchange: a social exchange perspective. Acad. Manag. J. **40**, 82–111 (1997)
26. Hobfoll, S.E.: Conservation of resources: a new attempt at conceptualizing stress. Am. Pscychol. **44**(3), 513–524 (1989)
27. Gallagher, V.C., Haris, K.J., Valle, M.: Understanding the use of intimidation as a response to job tension: career implication for global leader. Int. J. Career Dev. **13**, 648–666 (2008)

28. PriceWaterhouseCoopers: 2017 Ghana Banking Survey: Risk-based Minimum Regulatory Capital Regime: What it means for Banks in Ghana. PWC, Ghana (2017)
29. Parker, D.F., Decotiis, T.A.: Organizational determinants of job stress. Organ. Behav. Hum. Perform. **32**, 160–177 (1983)
30. Aquino, K., Lewis, M.U., Bradfield, M.: Justice constructs, negative affectivity and employee deviance: a proposed model and empirical test. J. Org. Beh. **20**, 1073–1091 (1999)
31. Twenge, J.M.: A review of the empirical evidence on generational differences in work attitudes. J. Bus. Psych. **25**, 201–210 (2010)
32. Twenge, J.M., Campbell, S.M., Hoffman, B.J., Lance, C.E.: Generational differences in work values: leisure and extrinsic values increasing, social and intrinsic values decreasing. J. Manag. **36**, 1117–1142 (2010)
33. Ghana Statistical Service: Ghana Living Standards Survey (GLSS 6): Main report. Ghana Statistical Service (2014)
34. Salgado, J.F.: The big five personality dimensions and counterproductive behaviours. Int. J. Sel. Ass. **10**, 117–125 (2002)
35. Skarlicki, D.P., Folger, R.: Retaliation in the workplace: the roles of distributive, procedural and interactional justice. J. Appl. Psychol. **82**(3), 434–443 (1997)
36. Vogelgesang, G.R., Leroy, H., Avolio, B.J.: The mediating effects of leader integrity with transparency in communication and work engagement/performance. Leadresh. Q. **24**(3), 405–413 (2013)

Quality of Work Life in Health Care Workers in Guadalajara, Mexico

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Abstract. The satisfaction with the Quality of Work Life (QWL) has great importance in the health of workers, the quality of work done, productivity and business efficiency. The aim of the study was to identify the level of satisfaction with the QWL in health care workers in Guadalajara, Mexico and it was done with doctors and nurses, from the three levels of care of an institution. The measurement was carried out with the CVT-GOHISALO instrument, designed to evaluate the QWL. The satisfaction with the QWL was measured by the seven dimensions of the instrument. The participating workers were 322, distributed in the three levels of care attention; 47.8% in the first level (154), 12.4% in the second level (40) and 39.8% in the third level (128). In all dimensions and for the three levels of attention we found more satisfaction than dissatisfaction. The second level workers are more satisfied than the other levels in three dimensions, the third level shows more satisfaction than the other levels in four of the seven dimensions and the first level does not stand out in any dimension.

Keywords: Quality of work life · Health care workers · Level of care

1 Introduction

The Quality of Work Life (QWL), also called Labor Quality of Life (LQL) by other authors, has recently become an important measure of the impact that the labor activity has on workers and organizations, is a broad concept that includes, in addition to satisfaction with the work being done, the achievements obtained through work and personal fulfillment, among other aspects. This has managed to arouse great interest for its study and measurement.

Being a multidimensional concept that includes objective and subjective elements, it offers a certain degree of difficulty for its evaluation; However, the existence of instruments for its measurement, which contemplate these aspects, allows us to have a broad view of the way in which workers evaluate it.

The concept of QWL is not new, but although it has been studied for several decades, it is still a term that offers an important difficulty to be defined in a precise way by the characteristics already mentioned; that is, it depends in large part on the values and

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beliefs of the workers, as well as on their cultural context and personal history, at the same time that it requires the evaluation of objective and subjective aspects in each of its dimensions, all of them related to the human needs. In it, the characteristics of work, the perception that the worker has with respect to it or the satisfactions that he/ she manages to obtain through his/her work receive the same weight, among others [1].

Its level of satisfaction in any of the dimensions that is evaluated has a great importance in the worker's health, in the quality of the work that he/she performs, in the productivity and in the business or institutional efficiency.

The QWL, has objective and subjective components, so for its evaluation it should be considered how people live the daily life of their work environment, taking into account their working conditions, both physical and contractual and remunerations, as well as his social relations both between colleagues and between the worker and the organization. The attitudes and values of workers and the perception of satisfaction or dissatisfaction derived from this set of factors are also very important [2].

The QWL presents methodological difficulties for its evaluation, based mainly on the fact that, within the multiple criteria found to assess it, there are few studies that present a concrete proposal to do so. The theoretical and methodological models found have been applied in other areas and in other places, without necessarily having the same application in the context of the Mexican health system [1].

To measure the QWL, the CVT-GOHISALO instrument was developed and validated in the Mexican population in 2007; which has a reliability of Cronbach's Alpha of 0.9527 and has validation of content, criterion and construct [3]; same that was selected to carry out this investigation.

On the basis of the instrument used for the evaluation of the QWL, which is defined as "a multidimensional concept that is integrated when the worker, through employment and under his/her own perception, sees the following personal needs covered: Institutional work support, Job reliability, Integration to the job and Satisfaction with it, identifying the well-being obtained through the job and the personal development achieved, as well as the administration of their free time" [3].

The CVT-GOHISALO, evaluates the QWL in seven dimensions, namely: Institutional work support, Job reliability, Integration to the job, Satisfaction with the work, Well-being obtained through the job, Worker's personal development and Free time administration [3].

The dimension Institutional work support, represents the elements of the job that are provided by the institution as a structure that shapes and supports employment, that of Job reliability is defined as the characteristics of employment that are related to the conditions that provide the worker with firmness in their relationship with the institution and includes satisfaction with the way in which the work procedures, income or salaries are designed, the inputs for carrying out the work, the contractual rights of the workers and the growth of their individual capabilities through training.

On the other hand, the dimension Integ ration to the job, is defined for this instrument as the insertion of the worker in the work as one of its parts, in total correspondence; and includes aspects of relevance, motivation and work environment. The Satisfaction with the work is understood as the overall feeling of liking or feeling good that the worker has regarding his employment. As for Well-being obtained through the job, it is understood as the mental or psychological state of satisfaction of needs related to the way of life, including the enjoyment of goods and riches achieved through work activity.

With regard to the last two dimensions of the instrument, the Worker's personal development is defined as the process of increasing personal aspects of the worker related to his/her work activity and that of Free time administration is defined as the way in which the worker enjoyed: life in the schedule in which work activities are not carried out [1].

Work is the activity of greatest importance for the human being, since he/she, individually or collectively, makes a series of contributions such as effort, time, skills and abilities, among others, specting for certain rewards that contribute to satisfying his or her needs, whether economic, material, psychological or social, among others, so it is essential to know the satisfaction with the QWL of workers [4].

The labor activity is the main contributor to raise the quality of life (QOL) of people and when the individual has the possibility of performing a job that corresponds to his/her capacity and vocation and identifies elements for personal growth in him or her, the level of his/her QWL will be higher.

The sense of responsibility, commitment and availability to the needs of sick people, are values that are considered appropriate for health professionals and are not required for other professions, which work very often under inadequate conditions such as absence of lapses of rest or feeding schedules and emotional exhaustion, in addition to the institutional demands of productivity and optimization of resources. For such reasons in health professionals high degrees of stress that can be accompanied by varying degrees of dissatisfaction are generated [5].

A very important aspect to consider, is that health work can be developed in formal health institutions, whether public or private and also in informality, where care is provided to other people, quite often without remuneration and caregivers, are exposed, based on the transfer that may occur between them and the people they care for, to be affected in their quality of life and in their mental health. This is explained by the type of activities that have to be developed in the care: adequate nutrition, personal hygiene, comfort and emotional and affective support [6].

Health services in Mexican institutions, both public and private, as well as in most countries of the world, must be provided on a continuous basis throughout the year, except in the primary care units where you work from Monday to Friday. Having to adapt the work activity to institutional needs, with shifts that in many cases includes the night, alters the family and social life of those who provide these services, which may even have repercussions on their own health. These working conditions in the health units, including family medicine units and hospitals, carry the risk of affecting the perception of satisfaction with the work activity developed, as well as with other personal needs intra and extra-labor [4].

The health institutions that make up the Mexican Health System are organized into three levels, classified based on the level of resolution and complexity of the services they provide: The first level includes the units that provide family medicine and preventive services, the second level those units that provide specialty care and the third level integrates units that provide highly specialized services.

Regarding the measurement of QWL in health professionals carried out in other investigations, we found a study that presents the results of the measurement of the Quality of Professional Life in the workers of Primary Care of Area 10 of Madrid, whose objective was to know the quality of professional life (QPL) perceived by primary health care workers in a health area, identifying the main components of it, in which a validated instrument, known as CVP-35, was used, which contains 35 items in 8 basic categories and their results show that the perception of QWL by health workers was medium and was interpreted as a place of work with enough resources but with a high workload and discomfort, as well as poor support from managers. However, they scored high on their level of motivation, training and social support [7].

With the same instrument as in the previous study (CVP-35), a QWL measurement was made of the graduates of the Faculty of Nursing of the National University San Luis Gonzaga of ICA, in Peru, finding 47.7% that qualified it as regular, 44.2% as good and only 8.1% as very good, however, the study does not explain the reasons for this rating [8].

According to Pérez and Zurita [9], who carried out a study to measure the quality of working life in public health workers in Chile, health organizations are one of the most complex environments to study, since they are present into them a large number of professionals and non-professionals that according to their level of well-being will have critical results for the members of the community; with activities that represent a high emotional load and insufficient support networks for these workers. For the measurement of the QWL they used the scale elaborated by Da Silva in 2006, which has 11 dimensions, which were correlated with the three dimensions of the Burnout Syndrome, finding a direct, statistically significant relationship between the satisfaction with the QWL and the dimension of Personal Realization of the Maslach Burnout Inventory and inverse between the QWL and emotional exhaustion and depersonalization.

With regard to studies conducted with the same instrument as in this research, the CVT-GOHISALO, we found some carried out in health workers, the fewer ones and some others carried out in other types of workers. For example, the study conducted by Moreno et al. [10], in health workers of a public institution in the State of Tamaulipas, Mexico, with a sample size of 372 subjects, in which they applied the scale to determine levels of satisfaction in the QWL in seven dimensions, finding that six of the dimensions qualified in medium level and one in low level, that is why it was concluded that the QWL of the health workers of Tamaulipas in the institution selected for study was bad.

Regarding the factors that influence the QWL of the nursing staff, an investigation carried out in the General Hospital of Zacatecas, México, reports that 58.1 percent of the nursing staff presented a low satisfaction percentage and only 9.7 percent were located in the category of high satisfaction; without performing analysis by dimensions, it concludes that the variables that influence these qualifications are the labor relationship with the organization, gender, type of service and workload [11].

Another application in health workers of the same instrument was carried out at the Río Blanco Clinic and the Medical Specialties Center in the city of Los Andes, in Chile, with the participation of doctors and nurses, who were qualified with the rates of the instrument as high, medium and low satisfaction in each of the seven dimensions of QWL, in the results of the 20 workers included, all the dimensions had a higher percentage of workers with low satisfaction, the dimension with the highest satisfaction percentage was the one of Institutional work support with 43% [12].

An example of a measurement of the QWL in non-health workers with the CVT-GOHISALO instrument is that carried out by workers of the Government Secretariat of the Municipality of Dosquebradas (Colombia), where the dimensions that obtained the highest satisfaction value were the one of Institutional work support and Well-being obtained through the job, the rest of the dimensions qualified as not satisfied [13].

The measurement made in sterilization auxiliaries of the Río Blanco Clinic, also in the seven dimensions handled by the CVT-GOHISALO instrument, presents results similar to the measurement made in doctors and nurses, all dimensions have an average evaluation [14].

The study conducted in public health workers in Chile, showed that QWL was significantly associated with job satisfaction and Burnout syndrome, also finding differences between managers and technicians [9].

On the other hand, a study was conducted in health professionals in Alicante, which was carried out on the occasion of a doctoral thesis, applying a questionnaire specifically designed for health workers, where it was found that, in relation to work, 97% of the health professionals report having a good or very good quality of life at work and 89% say they are satisfied with the work. Regarding satisfaction with specific aspects of the work of a health professional, they obtain the highest satisfaction in their relationship with patients [15].

2 Aim

The aim of the present study was to identify levels of satisfaction with the QWL in health workers from the three levels of care of an institution in Guadalajara, Mexico.

3 Methodology

The universe of work was constituted by 1866 doctors and nurses of a health institution, in its three levels of care in the Metropolitan Area of Guadalajara, all types of units and administrative offices were included, in all shifts of work.

A probabilistic sample was calculated, by strata, following the proportion in which the universe was distributed by levels of attention, leaving the following percentages; 47.8% in the first level (154), 12.4% in the second level (40) and 39.8% in the third level (128) (see Tables 1 and 2), they all were searched immediately by simple randomization in a census of workers per unit to individuals within each stratum, being visited in each health unit, level and shift they will meet.

The number of people interviewed was 322 and only those randomly selected were included, with a seniority minimum of six months and with any form of contracting.

The evaluation of the QWL was carried out in seven dimensions, which can be evaluated by means of the CVT-GOHISALO instrument: Institutional work support, Job reliability, Integration to the job, Satisfaction with the work, Well-being obtained through the job, Worker's personal development and Free time administration, which was applied to all selected individuals. The instrument allowed us to measure the satisfaction of the QWL in all its dimensions for the three levels of care and establish comparisons [1].

Table 1. Universe of study by health care levels of the selected institution

Health care level	Total staff	Doctors	%	Nurses	%
First level	814	481	25.8	333	17.9
Second level	369	122	6.5	247	13.2
Third level	683	215	11.5	468	25.1
Totals	1866	818	43.8	1048	56.2

Table 2. Conformation of the sample for study based on the proportions of the universe

Health care level	Doctors		Nurses	
	%	#	%	#
First level	25.8	91	17.9	63
Second level	6.5	23	13.2	46
Third level	11.5	450	25.1	88
Totals	43.8	154	56.2	197

4 Results

In all the dimensions, the percentage of satisfaction was greater than of non-satisfaction for the three levels of care; However, in four of the seven dimensions, dissatisfaction is greater for workers in the second level of care, reaching up to 35% of dissatisfaction with Worker's personal development.

The doctors and nurses of the second level of attention presented better qualification than those of the first and third levels in the dimensions of Well-being obtained through the job and Free time administration.

Regarding the work they do, the satisfaction is greater for the workers of the third level than for those of the other two levels, the other dimensions where these same workers stand out are in the Well-being obtained through the job and Free time administration.

The workers of the third level are more satisfied than those of the other two levels in five of the seven dimensions.

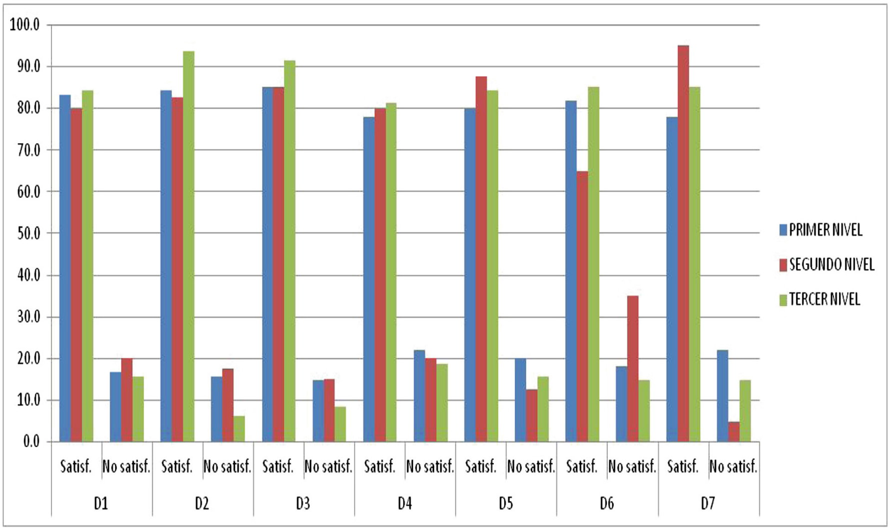
The ones of the first level does not stand out compared to the rest in any dimension.

The dissatisfaction in the QWL is greater for the workers of the first level of attention.

Compared to each other the three levels of attention, for the greater number of dimensions with higher dissatisfaction, the first level wins in three, the second level in four and the third level in none.

In the three levels of care, the dimension that presented the lowest level of satisfaction was the one of Satisfaction with the work, this result being more noticeable for the first and third levels of care. Finding the lowest satisfaction figures or higher non-satisfaction figures (20.5%) in this dimension, tells us that at least one fifth of our medical and nursing staff is dissatisfied with their work, that is, they do not have the overall feeling of liking or feeling good with respect to their employment, worrisome in people who dedicate themselves to the health care of others.

Being the dimension most affected for the three levels of care, it states that primary care workers are not satisfied with the activity they perform and allows us to identify the lack of commitment that the person shows towards the mission of the institution and with their own objectives, highlighting the negative aspects of the work and the dissatisfaction with the retribution that they obtain when performing their functions [16] (Fig. 1).



D1: Institutional work support
D2: Job reliability
D3: Integration to the job
D4: Satisfaction with the work
D5: Wel-being obtained through the job
D6: Worker's personal development
D7: Free time administration

Fig. 1. Percentage of satisfaction by dimensions and health care level

5 Discussion

There is a limited number of QWL studies with the same instrument as the one used in this study, which makes it difficult to compare them with other studies that have measured the satisfaction of the QWL of health personnel.

In the case of the studies by Moreno et al. [10], Herrera et al. [11] and Delgado et al. [12, 14], in health professionals, physicians, nurses and laboratory assistants, the measurements were made with the CVT-GOHISALO and present low or average measurements for all dimensions of the instrument, even more the study by Herrera et al. [11], does not analyze the qualification of the QWL by dimensions as the other studies, so this study is the one that presents percentages of satisfaction with the dimensions of the highest QWL.

None of the studies presented aims to specifically establish the levels of QWL, in each case the researchers establish their priorities directed mainly to psychosocial factors or Burnout Syndrome and mental health, such is the case of Marín et al. [17], which in 2005 had a prevalence of 25.6%, Ríos and Godoy [18] who obtained 25.5% and the results obtained in hospital professionals in training since 1992, by Breilh [19] with 71.8% of probable cases and the results of Juárez et al. [20], that when carrying out its study in six Latin American countries, he found in health professionals prevalences greater than 50% in 3 of them.

There is consensus in several of the studies presented and that have focused their efforts on the exploration of mental health in health personnel, the need to “care for caregivers”, even in the case of caregivers who are out of the formality [21], in order to improve the quality and the warmth of the health services provided by the subsystems that make up the Mexican health system, in accordance with the proposals of the World Health Organization.

The previous results show that despite the fact that health service providers have the responsibility of taking care of the health of the population in general and that our sample is made up of primary care employees in our country; They do not have any difference with the population in general.

Although the satisfaction with the QWL in all the dimensions of the CVT-GOHISALO is high, it is necessary to consider the levels of dissatisfaction to prevent damage to health and the development of other occupational risk factors in health workers, who have the responsibility of maintain health in the general population and should first seek, for themselves, an acceptable level of health [22].

6 Conclusions

For the health worker in developing countries, like ours, it is important to avoid the deterioration of their working conditions, since the impact is direct, affecting their quality of working life.

Evidence that health workers are not satisfied with the activity they perform, is important because of the relationship with the health care of the population in general.

In all the dimensions, the percentage of satisfaction was greater than of non-satisfaction for the three levels of care.

The workers of the third level are those who showed more satisfaction in terms of the work they do.

The QWL measured based satisfied was greater as the level of care increased.

Those of the first level did not stand out compared to the other two levels of attention in any dimension.

All dimensions presented more than 12% dissatisfaction.

The dimension most affected with dissatisfaction in the three levels of attention was “Satisfaction with the work”.

At least the 5th part of our doctors and nurses are dissatisfied with the activity they perform.

The low quality of work life affects the quality of the services provided to users.

It is urgent to design protection mechanisms from the organization to protect personnel working in health services, to promote the creation of social support networks and other measures aimed at preventing destructiveness at work.

It is necessary to establish preventive measures and control programs among healthcare workers to improve their QWL and other related factors.

References

1. González-Baltazar, R.: “Calidad de vida en el trabajo” Elaboración y validación de un instrumento en prestadores de servicios de salud. Tesis doctoral para obtener el grado de Doctora en Ciencias de la salud en el Trabajo, junio 2007. Universidad de Guadalajara (2007)
2. Llach, X.B., Tudela, L.L.: Estudios de Calidad de Vida. In: Zurro, A.M., Pérez, J.F.C. (eds.) Atención Primaria. Concepto, Organización y Práctica Clínica. Capítulo 15, 5ª Edición, pp. 250–256. Editorial Elservier. Madrid (2003)
3. González-Baltazar, R., Hidalgo, G., Salazar, J.G., Preciado, M.L.: Instrumento para medir la Calidad de Vida en el Trabajo CVT-GOHISALO, Manual para su aplicación e interpretación. Ediciones de la Noche, Guadalajara, México (2009). ISBN 978-970-764-866-1
4. Herrera, R., Cassals, M.: Algunos factores influyentes en la calidad de vida laboral de enfermería. Revista Cubana de Enfermería No. 2120 (2005)
5. Ramírez, M.A., Méndez-Carniado, O., Nigenda, G., Vargas, M.M.: Recursos humanos en los Servicios de Salud: Una perspectiva de género. Fundación Mexicana para la salud, Centro de Análisis Social y Económico (2002)
6. Bover, A.: Cuidadores informales de salud del ámbito domiciliario: percepciones y estrategias de cuidado ligadas al género y a la generación. (Tesis doctoral). Universitat de les Illes Balears, Departament de Ciències de L’educació) (2004)
7. Sánchez, R., Álvarez, R., Lorenzo, S.: Calidad de Vida profesional de los trabajadores de Atención Primaria del Área 10 de Madrid. MEDIFAM **13**(4), 291–296 (2003)
8. Córdova, M., Alvarado, S., Manrique, H., Lizarbe, C.R., Aguirre, S.E., Huaman, J.: Calidad de vida laboral de los egresados y predicamento del empleador. Facultad de enfermería de la Universidad Nacional “San Luis Gonzaga” de ICA. 2013. Rev. enferm. vanguard. **2**(2), 154–160 (2014)
9. Pérez, D., Zurita, R.: Calidad de vida laboral en trabajadores de salud pública en Chile. Salud & Sociedad **5**(2), 172–180 (2014)
10. Moreno, A., Aranda, C., Preciado, M., Valencia, S.: Calidad de vida laboral en trabajadores de la salud, Tamaulipas, México 2010. Cienc Trab. **13**(39), 11–16 (2011)
11. Herrera, M., Ruíz de Chávez, D., Almeida, C., García, P.: Factores que influyen en la calidad de vida laboral del personal de enfermería del Hospital General Zacatecas. Revista Electrónica Semestral Especializada en el Área de la Salud **2**(2), 1–13 (2011)

12. Delgado, D., Inzulza, M., Delgado, F.: Calidad de vida en el trabajo: profesionales de la salud de Clínica Río Blanco y Centro de Especialidades Médicas. Revista Medicina y Seguridad del Trabajo **58**(228), 216–223 (2012)
13. Barbosa, W.A., Orrego, J.M., Torres, A.L., Betancur, C.L., Tirado, P.C.: Calidad de vida laboral en trabajadores de la Secretaría de Gobierno del Municipio de Dosquebradas (Colombia). Revista Cultura del Cuidado **10**(1), 51–62 (2013)
14. Delgado, D., Aguilera, M.A., Delgado, F., Cano, I., Preciado, M.L., Ramírez, O.: Quality of life at work and working conditions in sterilization assistant. Am. J. Public Health Res. **2**(3), 108–112 (2014)
15. Peydró, C.: Calidad de vida, trabajo y salud en los profesionales sanitarios; un estudio en el hospital gemeral universitario de Alicante. (Tesis inédita de doctorado). Universidad de Alicante, España (2015)
16. González, R., Hidalgo, G., Salazar, J., Preciado, L.: Elaboración y Validación del Instrumento para Medir Calidad de Vida en el Trabajo “CVT-GOHISALO”. Ciencia & Trabajo **12**(36), 332–340 (2010)
17. Marín, N., Esteban, A., Palma, C., Vega, M., Mestre, L., Fornés, J.: Burnout en profesionales sanitarios en formación del Hospital Universitario Son Dureta. **9**(4) (2005). Psiquiatría.com
18. Ríos, M.I., Godoy, C.: Burnout y Salud percibidos en una muestra de enfermería de urgencias. Enfermería Intensiva **19**(4), 169–178 (2008)
19. Breilh, J.: Trabajo hospitalario, estres y sufrimiento mental, Deterioro de la salud de los internos en Quito, Ecuador. Repositorio institucional del Organismo Académico de la Comunidad Andina, CAN. Universidad Andina Simon Bolívar, Ecuador (1992)
20. Juárez, A., Vera, A., Merino, C., Gómez, V., Feldman, L., Hernández, E.: Demanda/Control y la Salud Mental en Profesionales de la Salud: Un Estudio en Seis Países Latinoamericanos. Información Psicológica **108**, 2–18 (2014)
21. Moreno, I., Antequera, R., Aires. M.M., Colado, S. Diaz, S.: Demanda de apoyo psicosocial en cuidadores de niños con enfermedades de baja prevalencia. Apuntes de Psicología **26**(2), 349–360 (2008)
22. González, R.: Calidad de vida en el trabajo; elaboración y validación de un instrumento en prestadores de servicios de salud. (Tesis inédita de doctorado). Universidad de Guadalajara, Guadalajara, México (2007)

Work Posture Analysis in the Ergonomic Assessment of Products - A Case Study

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Abstract. The article presents an example of an application for the analysis of the postures assumed on the job of product evaluation. The research undertaken by the authors concerned finding the ergonomic characteristics of work involving a swinging handle spade. In the course of their research, the authors used an electronic goniometer as well as a manual goniometer. During the test, a comparison was made of the positions assumed by the spade users: while using the handle and without using the handle.

A hand-held goniometer was also used for the analysis. Measurements with its use were made in relation to anthropometric points based on photographs of the postures assumed during the key activities performed by the subjects. A basic list of such activities was compiled, after which the angles between musculoskeletal system segments were measured.

The analyses shed light on the tested tool and the level of ergonomic quality achieved with its use.

Keywords: Ergonomic assessment · Musculoskeletal system
Fatigue · Goniometer · Electronic goniometer · Ergonomic quality

1 Introduction

In assessing the ergonomic conformity of products, it is essential to select assessment criteria that help account for both user capabilities and the conditions of application. Ergonomic compliance denotes a match between a product or process and the psychophysical characteristics of man. The match ensures that such a product or process does not add to human discomfort or adversely affect human health. Such compliance may be viewed as a standard of modernity [1–4]. Ergonomic assessment criteria have been laid down, among others, in international, European and Polish standards, such as:

- the draft standard PN-88/N-08007: Ergonomic certification of machinery and equipment [27];
- the repealed standard PN-81/N-08010: Ergonomic principles for the design of work systems [28];
- the repealed standard PN-83/N-08015 Ergonomics. Terminology. General concepts [29];

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- PN-EN 614-1:2006+A1:2009: Machine safety – Ergonomic design principles – Part 1: Terminology and general principles [17];
- PN-EN 614-2+A1:2010: Machine safety – Ergonomic design principles – Part 2: Interactions between machine design and work tasks [18];
- PN-EN ISO 6385: 2005 Ergonomic principles in the design of work systems [19];
- PN-EN ISO 12100:2012: Machine safety – General design principles – Risk assessment and mitigation [20];

One may also distinguish detailed criteria covering selected aspects of work environment relations such as:

PN-EN 894:2010: Machine safety – Ergonomic requirements for control indicator and item design [21];

- PN-EN 1005+A1: Machine safety – Physical capabilities of man: Part 1: Terms and definitions (2010) [22]; Part 2: Manual moving of machines and their parts (2010) [23]; Part 3: Recommended border values for machine operation (2009) [24]; Part 4: Assessment of working body postures and motions relative to machine (2009) [25]; Part 5: Assessment of risks involved in performing highly repetitive activities (2007) [26];
- ISO 11226:2000: Ergonomics - Evaluation of static working postures [10];
- ISO 11228 Ergonomics — Manual handling: Part 1: Lifting and carrying (2003) [11]; Part 2: Pushing and pulling (2007) [12]; Part 3: Handling of low loads at high frequency (2007) [13].

For each of the areas named next to the standards, detailed rules have been developed covering the management of work environment relations and analysis methods.

2 Methods - An Example of the Ergonomic Conformity of a Tool

The study concerns identifying the ergonomic features of work with a spade fitted with an adjustable handle that has been designed and patented by its designer [14]. The handle is fastened onto the shaft of a spade or shovel (Fig. 1). It allows an adult hand to grasp around the handle (using the power grip, as described in the applicable standard) and adjust the way the tool is held during work. As the spade is used, the handle affects changes in:

- the distribution of forces acting upon the hand and the user’s musculoskeletal system;
- the angles at which individual segments of the user’s musculoskeletal system are positioned.

A direct modification of work methods with the use of the tools examined may indirectly influence:

- the total energy expended in the course of performing the work;
- the fatigue levels arising in individual muscle groups.

The above theses required verification by way of:

(a) ascertaining the angles at which the individual segments of the musculoskeletal system were positioned and assessing the degree to which such angles were acceptable:
   - such an ascertainment is possible by measuring the angles at which musculoskeletal system segments are positioned with the use of goniometers (analog or electronic);
   - ergonomic risk assessment methods or standards for determining the acceptability of specific positions may be used in such an assessment.

(b) measuring the forces that act upon hand surfaces using tensometric sensor devices;
(c) measuring the effective energy expended while performing work with and without the handle.

a) b) c)

Fig. 1. Spades with a handle mounted on: (a) a metal shaft, (b) a wooden shaft, (c) a wooden shaft in a high position (Photographs by G. Dahlke).

The measurements of the angles at which the segments of the musculoskeletal system are positioned may differ depending on a range of work process characteristics. These include:

- measurement accuracy (estimation methods, measurement methods, etc.);
- the organization of the manufacturing process (production stabilization level - linear, nested, etc., division of tasks)
- the nature of loads impacting upon individual muscle groups and musculoskeletal system segments (dynamic and static work);
- the labor intensity of the study;
- the equipment and measuring instruments available.

In the course of their research, the authors used:

- an electronic Biometrics ltd goniometer (DataLOG, type P3X3) [9], as well as
- observations of photographic material prepared using a manual goniometer.

Changes in the position of the upper limb (the right limb in the case of the subjects) were recorded continuously (in a discrete 20 Hz recording) while the subjects used the concerned handle. The research covered the use of two tools:

- a spade with a metal handle,
- a spade with a wooden handle;

During the test, a comparison was made of the positions assumed by the spade users:

- while using the low handle [14];
- without using the low handle.

Also assessed was the impact of adjustments in the height of the adjustable handle on worker performance.

During the study and analysis, posture was assessed using the following methods:

- Work Method Audit, designed to the PN-EN 1005-4 and ISO 11226 standards [8, 10, 25],
- REBA (Rapid Entire Body Assessment) [7],
- RULA (Rapid Upper Limb Assessment) [16].

Due to the technical specifications of electronic goniometers (insufficient sensor span), no torso angle measurements were taken during the course of work performance. A hand-held goniometer was also used for the analysis. Measurements with its use were made in relation to anthropometric points based on photographs of the postures assumed during the key activities performed by the subjects. Such key activities are those which force or determine the positions of musculoskeletal system segments while work is performed in a specific way during the use of work tools. A basic list of such activities was compiled, after which the angles between musculoskeletal system segments were measured.

The analyses shed light on the tested tool and the level of ergonomic quality achieved with its use.

3 Results of Investigation

The findings are presented using two human subjects (whose body measurements differ considerably – Table 1). Before the measurements, the key postures assumed by the subjects during garden work were identified. A list of such postures with exam-ples for Subject 2 are shown in Table 2.

The following have been assessed for each subject:

- work with a metal handle-shaft shovel using the low handle;
- work with a wooden handle-shaft shovel using the low handle;

– work with a wooden handle-shaft shovel using the low handle mounted in a high position;
– work with a metal handle-shaft shovel without the low handle;
– work with a wooden handle-shaft shovel without the low handle.

Electronic goniometer sensors were placed on the upper limbs of the subject (Fig. 2). They recorded on a memory card the locations of segments of the worker's muscoskeletal system during the use of shovels. The goniometer measurements were taken with the use of the Biometrics DataLog application (a version licensed for the Ergonomics and Occupational Risk Laboratory of the Poznań University of Technology) [9]. The angle (positive or negative) indicated the position of the limb during the performance of work. The key statistics are summarized in Table 3.

Table 1. Anthropometric characteristics of the subjects in standing position (value taken from Atlas [6]) (Source: Own work).

Name of anthropometric characteristics	Value of characteristic – Subject 1 [mm]	Value of characteristic – Subject 2 [mm]	Percentile C5 - female [mm]	Percentile C95 - male [mm]
Stature	1580	183	1524	1854
Acromion height	1270	1490	1241	1530
Elbow height	940	1110	913	1135
Arm reach forward (to the axis of the grip)	670	770	671	832
Acromion breadth	400	485	358	487
Knee height	420	495	385	508
Arm reach down (to the axis of the grip)	680	785	626	776

Angles of muscoskeletal system segments were recorded for the right upper limb (both subjects were right-handed), whose hand was used on the adjustable handle. The analysis focused on movements of the wrist (bending), the forearm (bending and twisting) and the upper limb (extension, back-leaning and lifting). Detailed results are shown in Figs. 3 and 4.

Despite the absence of recommendations by the manufacturer, an electronic goniometer was used to track shoulder joint movements. Angular adjustments for RULA and REBA assessments were gauged on photographs by means of a manual goniometer. The electronic goniometer made it possible to identify the number of upper limb lifts and extensions.

Table 2. Key activities and the associated postures during work with a metal-shaft spade using a low handle – Subject 2 (Source: Own work; Photographs by M. Drzewiecka-Dahlke).

No.	Name of key activities	Photographs of key activities
1	Starting work posture	
2	Posture immediately before spade blade is driven into the ground with a foot	
3	Driving of spade blade into the ground	
4	Breaking of ground – application of leverage	
5	Posture preceding dirt lifting	
6	Dirt unloading from spade after blade is turned over	

Fig. 2. Sample mounting of goniometers and torsiometer for Subject 2 (Photographs by M. Drzewiecka-Dahlke).

A comparison of cases of using and not using the low handle has led me to the following conclusions (Fig. od 3 do 4):

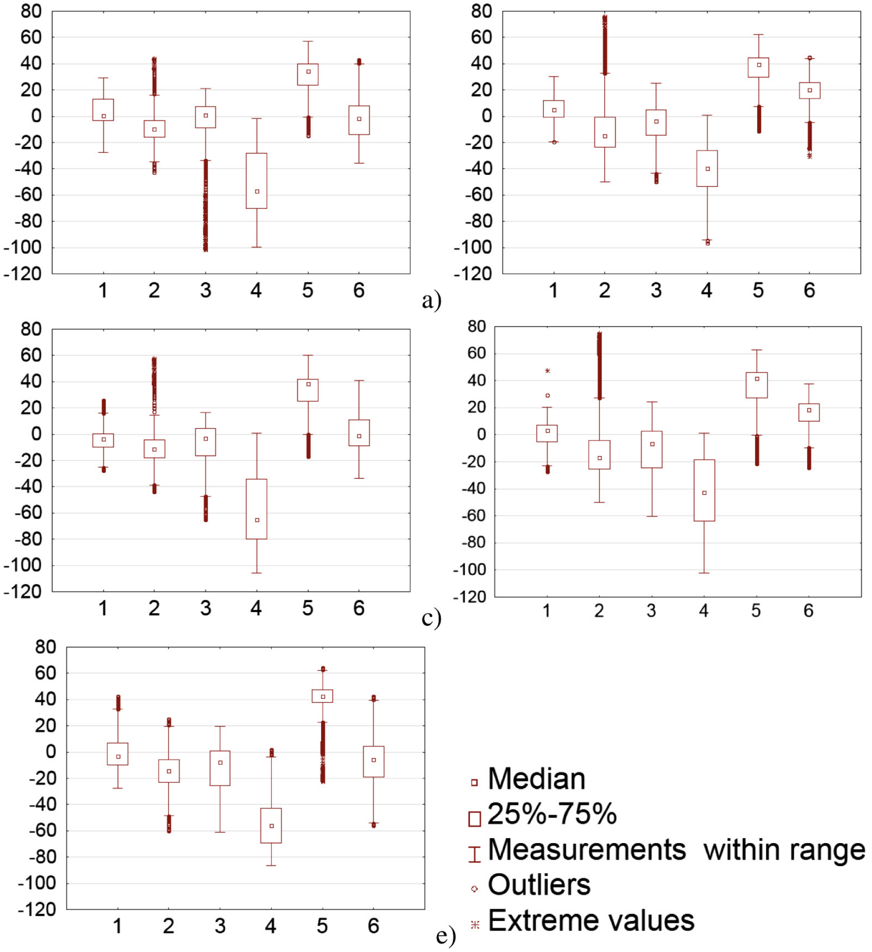

Fig. 3. Upper limb segment angles (in degrees) assumed by Subject 1 during work with: (a) a metal-shaft spade using the low handle; (b) a metal-shaft spade without using the low handle; (c) a wooden-shaft spade using the low handle; (d) a wooden-shaft spade without using the low handle; (e) a wooden-shaft spade using the low handle mounted in a high position; 1 - hand-forearm (wrist ulnar abduction+); 2 - hand-forearm (wrist extension+); 3 - forearm-upper arm (elbow flexion−; elbow extension+); 4 - upper arm-shoulder (abduction−); 5 - upper arm-shoulder (flexion+; extension−); 6 - forearm pronation−; supination+) (Source: Own work).

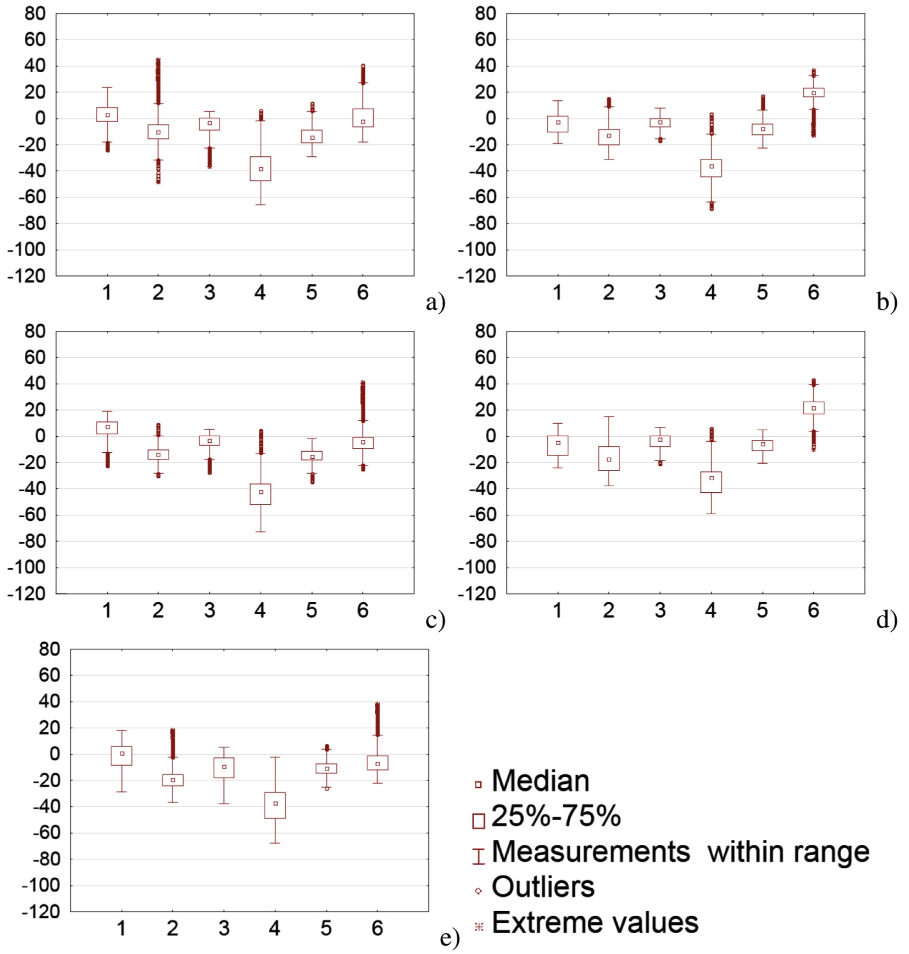

Fig. 4. Upper limb segment angles (in degrees) assumed by Subject 2 during work with: (a) a metal-shaft spade using the low handle; (b) a metal-shaft spade without using the low handle; (c) a wooden-shaft spade using the low handle; (d) a wooden-shaft spade without using the low handle; (e) a wooden-shaft spade using the low handle mounted in a high position; 1 - hand-forearm (wrist ulnar abduction+); 2 - hand-forearm (wrist extension+); 3 - forearm-upper arm (elbow flexion−; elbow extension+); 4 - upper arm-shoulder (abduction−); 5 - upper arm-shoulder (flexion+; extension−); 6 - forearm pronation−; supination+) (Source: Own work).

- The use of a adjustable handle on a metal-shaft spade by Subject 1 has:
  - reduced the outward bending angle of the right wrist,
  - reduced the downward bending angle of the right wrist,
  - increased the lateral extension angle of the right upper limb,
  - reduced the lifting angle of the right upper limb,
  - substantially reduced the outward twisting angle of the right forearm.
- The use of the adjustable handle on a wooden-shaft spade by Subject 1:
  - reduced the downward bending angle of the right wrist,
  - reduced the bending angle of the right forearm at the elbow,
  - increased the lateral extension angle of the right upper limb,
  - slightly reduced the lifting angle of the right upper limb,
  - substantially reduced the outward twisting angle of the right forearm.
- The upward adjustment of the swinging handle on a wooden-shaft spade by Subject 1:
  - increased the lateral extension angle of the right upper limb,
  - slightly increased the lifting angle of the right upper limb,
  - slightly increased the inward twisting angle of the right forearm.
- The use of the swinging handle on a metal-shaft spade by Subject 2:
  - reduced the inward bending angle of the right wrist,
  - reduced the upward bending angle of the right wrist,
  - increased the backward extension of the right upper limb,
  - substantially reduced the outward twisting angle of the right forearm.
- The use of the swinging handle on a wooden-shaft spade by Subject 1:
  - reduced the inward bending angle of the right wrist,
  - reduced the upward bending angle of the right wrist,
  - reduced the bending angle of the right forearm at the elbow,
  - increased the extension angle of the right upper limb,
  - slightly increased the lifting angle of the right upper limb,
  - substantially reduced the outer twisting angle of the right forearm.
- The upward adjustment of the swinging handle on a wooden-shaft spade by Subject 1:
  - increased the lateral extension angle of the right upper limb,
  - slightly increased the lifting angle of the right upper limb,
  - slightly reduced the inward twisting angle of the right forearm.

Table 3. Positions of the right upper limb in Subject 1 and Subject 2 while working with spades (Source: Own work).

No.	Type of spades and the way it is used	Measurement time [min:s,0] (min)		Hand-forearm (wrist ulnar abduction+)	Hand-forearm (wrist extension+)	Forearm-upper arm (elbow flexion−; elbow extension+)	Forearm pronation−; supination+)
Subject 1							
1	A metal-shaft spade using the low handle	02:47,7 (2,7943)	Min. angle	−27,36°	−42,705°	−101,655°	−35,91°
			Max. angle	29,025°	44,1°	20,925°	43,02°
2	A wooden-shaft spade using the low handle	02:06,78 (2,113)	Min. angle	−27,36°	−43,83°	−65,295°	−33,885°
			Max. angle	25,965°	57,465°	16,605°	40,995°
3	A wooden-shaft spade using the low handle mounted in a high position	02:31,7 (2,5286)	Min. angle	−27,765°	−59,85°	−60,975°	−56,115°
			Max. angle	42,435°	25,2°	19,53°	42,39°
4	A metal-shaft spade without using the low handle;	02:27,44 (2,457)	Min. angle	−19.395°	−50.04°	−49.77°	−30.735°
			Max. angle	30.285°	76.095°	25.245°	45.09°
5	A wooden-shaft spade without using the low handle	02:07,02 (2,117)	Min. angle	−27.495	−50.13	−60.21	−24.255
			Max. angle	47.655	74.97	24.255	37.71
Subject 2							
6	A metal-shaft spade using the low handle	01:16,7 (1,278)	Min. angle	−23,94	−48,645	−36,72	−18
			Max. angle	23,805	44,865	5,31	40,635
7	A wooden-shaft spade using the low handle	01:04.3 (1,07167)	Min. angle	−22,545	−30,24	−27,81	−24,885
			Max. angle	18,99	8,82	5,445	41,4
8	A wooden-shaft spade using the low handle mounted in a high position	01:04,9 (1,08167)	Min. angle	−28,53	−36,675	−37,71	−21,96
			Max. angle	18,225	18,63	5,175	38,34
9	A metal-shaft spade without using the low handle;	00:59,7 (0,9953)	Min. angle	−19.125	−31.23	−16.875	−13.05
			Max. angle	13.275	15.12	7.74	36.945
10	A wooden-shaft spade without using the low handle	01:04,2 (1,07067)	Min. angle	−24.075	−37.665	−21.06	−10.26
			Max. angle	10.125	15.12	6.705	43.155

Table 4. Assessments of key postures by the REBA method (Source: Own work).

Description of the assessment	REBA [7]			
	REBA score left	SD REBA score left	REBA score right	SD REBA score right
Averages for spades – a person of short stature (Subject 1)				
A metal-shaft spade using the low handle	8.50	0.8367	8.00	0.6325
A wooden-shaft spade using the low handle	8.50	1.0488	7.67	0.5164
A wooden-shaft spade using the low handle mounted in a high position	8.33	0.8165	7.50	0.5477
A metal-shaft spade without using the low handle	8.33	0.8165	7.33	0.5164
A wooden-shaft spade without using the low handle	8.67	1.0328	7.67	0.5164
Averages for spades - a person of high growth (Subject 2)				
A metal-shaft spade using the low handle	8.67	1.3663	8.00	0.8944
A wooden-shaft spade using the low handle	8.17	0.9832	7.50	0.5477
A wooden-shaft spade using the low handle mounted in a high position	8.00	0.8944	7.17	0.4082
A metal-shaft spade without using the low handle	8.17	0.7528	7.83	0.9832
A wooden-shaft spade without using the low handle	8.00	1.2649	7.67	0.8165

SD – standard deviation

Further conclusions regarding the tool can be drawn from applying the REBA and RULA methods [7, 16]. The findings for the assessed cases are summarized in Tables 4 and 5. A detailed analysis of torso and upper limb angles shows that the use of the handle enabled the subjects to reduce their torso tilt angle. That angle ranged from 20° (when the handle was used) to 60° (when no handle was used). Neither the REBA nor the RULA assessment helped differentiate between the two options. Another risk gauging challenge was to quantify wrist bending. Yet, step 9a of the REBA assessment assigns the same value to upper limb bending and twisting. The use of a handle that decreases forearm twisting did not reduce the score as the upper limb remained slightly bent. Significant score differentiation was observed in the RULA assessment whose step 4 allowed for an independent evaluation of forearm twisting. The results additionally accounted for differences between the anthropometrics of the two subjects. The reach of Subject 2 ended considerably higher (Table 1) forcing him to lean his torso at a greater angle when working with a handle in a lower position.

Table 5. Assessments of key postures by the RULA method

Description of the assessment	RULA [16]			
	RULA score left	SD RULA score left	RULA score right	SD RULA score right
Averages for spades – a person of short stature (Subject 1)				
A metal-shaft spade using the low handle	6.83	0.4082	6.00	0.0000
A wooden-shaft spade using the low handle	6.83	0.4082	6.00	0.0000
A wooden-shaft spade using the low handle mounted in a high position	7.00	0.0000	6.00	0.0000
A metal-shaft spade without using the low handle	7.00	0.0000	6.17	0.4082
A wooden-shaft spade without using the low handle	7.00	0.0000	6.50	0.5477
Averages for spades - a person of high growth (Subject 2)				
A metal-shaft spade using the low handle	7.00	0.0000	6.00	0.0000
A wooden-shaft spade using the low handle	6.83	0.4082	6.00	0.0000
A wooden-shaft spade using the low handle mounted in a high position	6.83	0.4082	6.00	0.0000
A metal-shaft spade without using the low handle	6.67	0.5164	6.33	0.5164
A wooden-shaft spade without using the low handle	6.50	0.5477	6.17	0.4082

SD – standard deviation

4 Conclusion

The analysis of the findings provided in the preceding chapter has shed light on both the product in question and the methods employed. When assessing the product by the biomechanical criterion, it is critical to select the methods carefully. Where the applied ergonomic solutions result in slight changes in the angles of muscoskeletal system segments, methods that classify angles into broad ranges offer little help in differentiating between assessment outcomes and, as a consequence, make it impossible to benefit from the effort.

The substantial differences between the anthropometric measurements of the subjects had no significant effect on the assessment outcomes.

Further research on the product in question will be extended to, inter alia, the energy expanded during work, defining recommendations on the height at which the handle should be mounted and identifying the most advantageous work techniques.

References

1. Dahlke, G., Drzewiecka, M.: Conception of the quantification of subjective ergonomic criteria in the network thinking method. In: Tareq, A., Waldemar, K., Dylan, S. (eds.) Proceedings of 6th International Conference on Applied Human Factors and Ergonomics (AHFE 2015) and the Affiliated Conferences, Procedia Manufacturing, vol. 3, pp. 4844–4851. Elsevier B.V (2015)
2. Dahlke, G.: Ergonomic criteria in the investigation of indirect causes of accidents. In: Tareq, A., Waldemar, K., Dylan, S. (eds.) Proceedings of 6th International Conference on Applied Human Factors and Ergonomics (AHFE 2015) and the Affiliated Conferences, Procedia Manufacturing, vol. 3, pp. 4868–4875. Elsevier B.V (2015)
3. Dahlke, G.: Modelowanie symulacyjne w ergonomii i bezpieczeństwie pracy. In: Zeszyty Naukowe Politechniki Poznańskiej, seria Organizacja i Zarządzanie, No. 63, Poznań (2014)
4. Dahlke, G., Repiński, M., Śnieżko, P.: Ocena ergonomiczności stanowisk pracy motorniczych tramwajów. In: Logistyka/Instytut Logistyki i Magazynowania. - 2014, Materiały XI Konferencji Naukowo-Technicznej: Logistyka, systemy transportowe, bezpieczeństwo w transporcie LogiTrans, Szczyrk, 07–10 kwietnia (2014)
5. Dahlke, G., Sasim, J., Sasim, B.: Analiza biomechaniczna obciążenia pilota samolotu M - 28 Bryza: In: Logistyka/Instytut Logistyki i Magazynowania (2014)
6. Gedliczka, A.: Atlas miar człowieka. Dane do projektowania i oceny ergonomicznej. Wyd. CIOP, Warszawa (2001)
7. Hignett, S., McAtamney, L.: Rapid Entire Body Assessment (REBA). Appl. Ergon. **31**, 201–205 (2000)
8. Horst, W.: Ryzyko zawodowe na stanowisku pracy. Część I Ergonomiczne czynniki ryzyka. Wyd. Politechniki Poznańskie, Poznań (2004)
9. http://biometricsltd.com
10. ISO 11226:2000 Ergonomics - Evaluation of Static Working Postures
11. ISO 11228:2003 Ergonomics — Manual Handling. Part 1: Lifting and Carrying
12. ISO 11228:2007 Ergonomics — Manual Handling. Part 2: Pushing and Pulling
13. ISO 11228:2007 Ergonomics — Manual Handling. Part 3: Handling of Low Loads at High Frequency
14. Krzempek, A.: Handle for the Shovel and Spade, Patent and Utility Model
15. Marcinkowski, J.S., Zielniewicz, P.: Ergonomiczność kabiny motorniczego tramwaju 105N/2. w: Zeszyty Naukowe Politechniki Poznańskiej. Organizacja i Zarządzanie, Poznań (1998)
16. McAtamney, L., Corlett, E.N.: RULA: a survey method for the investigation of work-related upper limb disorders. Appl. Ergon. **24**(2), 91–99 (1993)
17. PN - EN 614-1:2006+A1:2009 Bezpieczeństwo maszyn - Ergonomiczne zasady projektowania - Część 1: Terminologia i zasady ogólne
18. PN-EN 614-2+A1:2010 Bezpieczeństwo maszyn - Ergonomiczne zasady projektowania - Część 2: Interakcje między projektowaniem maszyn a zadaniami roboczymi
19. PN-EN ISO 6385: 2005 Ergonomic principles in the design of work systems
20. PN-EN ISO 12100:2012 Bezpieczeństwo maszyn – Ogólne zasady projektowania – Ocena ryzyka i zmniejszanie ryzyka
21. PN-EN 894:2010 Bezpieczeństwo maszyn – Wymagania ergonomiczne dotyczące projektowania wskaźników i elementów sterowniczych
22. PN-EN 1005+A1:2010 Bezpieczeństwo maszyn - Możliwości fizyczne człowieka – Część 1: Terminy i definicje

23. PN-EN 1005+A1:2010 Bezpieczeństwo maszyn - Możliwości fizyczne człowieka – Część 2: Ręczne przemieszczanie maszyn i ich części
24. PN-EN 1005+A1:2009 Bezpieczeństwo maszyn - Możliwości fizyczne człowieka – Część 3: Zalecane wartości graniczne sił przy obsłudze maszyn
25. PN-EN 1005+A1:2009 Bezpieczeństwo maszyn - Możliwości fizyczne człowieka – Część 4: Ocena pozycji pracy i ruchów w relacji do maszyny
26. PN-EN 1005+A1:2007 Bezpieczeństwo maszyn - Możliwości fizyczne człowieka – Część 5: Ocena ryzyka dotycząca czynności wykonywanych z dużą częstością powtórzeń
27. PN-88/N-08007 Atestacja ergonomiczna maszyn i urządzeń (draft standard)
28. PN-81/N-08010 Ergonomiczne zasady projektowania systemów pracy (standard has expired)
29. PN-83/N-08015 Ergonomia. Terminologia. Pojęcia ogólne (standard has expired)

Human Factors in Sports and Amusement Industry

Federal Legislation: Regulation of Ride System G-forces Versus Amusement Industry Autonomy: Designing for Human Endurance

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Abstract. Millions of guests visit amusement parks to experience an immersive form of entertainment with low incidence of injury. The amusement industry is self-regulating and maintains one of the highest safety records for recreational activities according to statistical data collected by several industry sources. Despite the low accident rate, congressional members and safety advocates lobby for federal legislation for the regulation of g-force limits on ride systems. Several components encompass the biomechanics of ride systems design. The amusement industry uses voluntary consensus standards developed by industry experts, state officials, engineers, academia, and park owner-operators for ride systems design. Therefore, the intent of this paper is to compare industry data to determine if g-forces experienced on rides systems warrant federal legislation or is industry autonomy more relevant due to the ability to draw upon the expertise of industry professionals to develop standards that guide ride design and regulate an industry as it tests the boundaries of human endurance.

Keywords: Amusement rides · Safety · Biomechanics · G-forces
Linear acceleration · Radial acceleration

1 Introduction

With fierce competition and rapid growth of the amusement industry, fixed theme parks are developing all over the world and innovation is allowing the industry to produce larger and more thrilling amusement rides. Patrons experiencing amusement rides is a popular practice for being entertained and having fun. According to the International Association of Amusement Parks and Attractions (IAAPA), over 372 million guests visit amusement parks yearly; whereby, patrons realize more than 1.7 billion safe ride experiences a year. They estimate the probability of injury resulting from a fixed-site amusement ride is less than 1 in 17 million (2015).

Despite the stellar safety record of the amusement industry, high profile incidents in the industry provide a perception that "ride technology" has gotten out of hand and prompted members of congress to author language for legislation to allow the federal government to regulate g-force limits on amusement rides. The amusement industry uses voluntary consensus standards developed by industry experts, state officials, ride engineers, academia, park owner-operators, and consumer advocates for the design of

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ride systems and devices. The intent of this paper is to compare industry data and trends to determine if g-force limits induced by amusement rides warrant federal legislation or is industry autonomy more relevant due to the ability to draw upon the expertise of industry professionals.

2 Background

The industry is largely self-regulating and maintains one of the highest safety records for recreational activities according to several sources [1–3]. Ride accidents are a rare occurrence [4] and even rarer are brain injuries associated with ride systems experiences. The industry has over 400 fixed-site parks in the United States. For the International Association of Amusement Parks and Attractions (IAAPA), safety is the organization's highest priority for the amusement industry. At the same time, others contend federal oversight will improve safety in the industry, while others argue federal control will only serve to weaken an effective system for maintaining safety by luring inspectors from state agencies in order to staff up. Additionally, in order to regulate and control design criteria there needs to be a clear understanding of the technology.

2.1 Ride Systems Dynamics

Intimate knowledge of the ride dynamics is the most important aspect of the ride design. The biomechanical impacts to the patron due to g-forces depend largely on the design of the ride system. There are many factors that influence the effects of accelerations/decelerations, most of which can be altered as part of the design to minimize the impact of g-forces. The industry boasts very complex systems with many components influencing g-force limits, therefore, the designer-engineer is required to perform a ride analysis [5], which considers the overall design components associated with valleys, curves, speed, hills, and radius of curvature to determine the forces. Despite the rare occurrence of amusement ride incidents, any accident creates an adverse response from the media and public that extends well beyond the accident venue, whereby, the safety of the entire amusement industry comes into question.

2.2 Industry Consensus Standards

Understanding the hazards associated with ride systems design, operation and maintainability are a real consideration for ride designers of the amusement industry. For the last forty years, amusement industry experts, worldwide, have come together to develop the most successful and comprehensive set of safety consensus standards for the design of amusement ride systems and devices. The American Society of Testing and Materials (ASTM*i*), F2291-17, *Standard Practice for Design of Amusement Rides and Devices*, section 7.0 on acceleration limits, identifies the requirements for acceleration limits, which need to consider the ride dynamics as part of the design. Validation of the as-installed equipment is required during commissioning through data acquisition of measured g-forces and duration, in compliance with ASTM*i*, F2137-16, *Standard Practice for Measuring the Dynamic Characteristics of Amusement Rides and Devices.*

In the United States, the standardization system incorporates government and non-government agencies and classifies standards into two categories; mandatory and voluntary. The distinction between voluntary and mandatory standards is rooted in the development nature of the specifications. Mandatory standards are the development efforts of government agencies, which largely adopt private sector standards by reference. When mandatory standards reference voluntary standards in regulations, that reference promulgates the standard, and becomes federal, state and local law and shall be adhered to. The Environmental Protection Agency (EPA) or the Occupational Safety and Health Administration (OSHA) are regulatory agencies that reference voluntary consensus standards under their jurisdiction and are examples of government standards.

Voluntary consensus standards are developed by all sectors that have an interest and need for the use of a standard. Consensus standards are considered by many as the most technically sound and most credible documents [6]. The U.S. National Technology Transfer and Advancement Act (Public Law104-113), which requires government agencies to use privately developed standards whenever possible, increased the use of voluntary consensus standards [6].

Standards consensus is established by an eclectic group of experts from around the world with intimate knowledge of the technology governed by the standards. There is an exception to this statement and that is when the technology is so technically advanced that it has no peers. In this case, these standards are recognized and have international acceptance no matter how they were developed [7].

2.3 Amusement Ride Oversight

From 1972 until 1981, the U. S. Consumer Product Safety Commission (CPSC) had jurisdiction over fixed-site amusement rides. However, in 1981, congress concluded that customers buy the services or experiences of amusement rides; therefore, they elected to remove control of fixed-site amusement rides from the CPSC arguing that it is the facility that buys the product. Since then, safety advocates in congress have been trying to get control back for the oversight of amusement-park-rides. Their position gains traction any time there is an unfortunate accident associated with the industry. There was a spike in amusement park ride injuries over a four-year period (1996–2000) that required emergency room treatment; however, less than 5% of these injuries required an overnight stay (IAAPA 2014). In order to regulate fixed-site amusement rides the CPSC estimates it would require over 68MM dollars and doubling its staff to more than 900 employees. Many argue the only place to recruit skilled and certified individuals is from the state level, leaving a gaping hole for state agencies.

2.4 Lobbying for Federal Legislation

Legislators tried to get a bill passed to set up a federal agency that would provide oversight for the amusement parks but the bill failed to get passed. Ever since joining congress over 20 years ago, Senator Markey (D-MA) introduced legislation at several congressional sessions to reinstate federal oversight of amusement parks. The senator's campaign began after a string of accidents in 1999 when there were four accidents, blaming the tragedies on the increased speed, height, and intensity of the nation's roller coasters [8]. He insists that the industry is bending to the will of a competitive market where technology is testing the limits on safety. At one point in 2002, Markey, gained support at the state level and some states adopted g-force limits for new attractions without any empirical data to indicate where the limits should be and under what conditions. By 2003 he was able to fuel his cause enough that congress granted him an opportunity to validate his claim. Therefore, Six-Flags commissioned the American Association of Neurological Surgeons (AANS) to study the impact of g-forces on the brain. The consensus of the study was a big disappointment for Senator Markey. Refusing to concede with the findings of the AANS 2003 study, in 2011, he asserted, *"The amusement-park-ride industry pulls out all the stops to prevent his proposals from moving forward in congress* [8]*."*

2.5 The Science of Biomechanics

Published research on the effects of g-forces of high-energy rides is minimal. The U. S. Navy and NASA are the two agencies that engage in research related to g-forces and have the most extensive data. During WWII Colonel John Paul Stapp developed solutions for the problems that existed for fighter pilots at high altitudes. His successes lead to a unique opportunity to do research in a new area of science known as biomechanics relative to human factors. His work required research to determine the human body's ability to handle g-forces. There was a lot of controversy over the highest g-force the body could withstand. Most believed 8 gs was the maximum. He first studied the effects of deceleration and in early tests he survived over 35 gs, and later survived 45 gs. In addition to deceleration forces, he also studied the effects of onset, the rate at which forces build. Stapp personally survived more than double the maximum g-force limits in tests he performed but he knew the human body could take much more; however, it was clear that while the body could withstand higher g-forces, the eyes experienced white out and red out from broken capillaries and hemorrhaging when g-forces reach 18gs.

3 Method and Results

Height and speed are only two of the components of ride design that influence forces. Additional contributors to the magnitude of forces depend on the combination of how hills, valleys, and the radius of curvature come together in the design of the track system. Where V = velocity and R = radius of curvature, the standard physics equation for force is:

$$F = V^2/R. \tag{1}$$

Using the same formula, when the radius of curvature of a coaster increases four times and the speed doubles, the resultant force is the same.

$$F = (V * 2)^2/R * 4. \tag{2}$$

Hence, for a coaster traveling at 50 mph for a given radius of curvature of 40 feet, the resultant force will be the same for a coaster speed of 100 mph speed with a radius of curvature of 160 feet.

Other elements affecting the magnitude of force due to acceleration is the type of acceleration.

- Linear acceleration happens when there is an increase in speed without a change in direction. Linear acceleration is usually the easiest to tolerate.
- Radial acceleration occurs when there is a change in direction but speed stays constant.
- Angular acceleration is when change in both speed and direction occur. Angular acceleration poses one of the greatest risk for injury. However, injury may result from magnitude and rate of energy absorption into tissues, regardless of the source.
- Acceleration vectors for roller coasters act in three primary axis: lateral, fore/aft, and vertical directions.
- Vertical accelerations are usually higher and act along the spine but do not produce any appreciable rotational acceleration to the head.

Accelerations have components of magnitude, duration, and direction that effect the response to the g-force experience, and the limits need to include the combination of all the g-forces.

3.1 Ride Injury Reporting

The attractions industry maintains an active safety program, but detailed data are not widely released to the public and therefore not available for this study. However, several secondary sources that collect and archive reports of amusement ride injuries make their databases available. The affiliation for data sources resides with non-profit, government, public service, advocacy, regulatory, and trade organizations (Table 1).

Table 1. Data sources.

Organization	Website
Amusement Safety Organization	amusementsafety.org
National Electronic Injury Surveillance System	CPSC.gov
National Safety Council	nsc.org
SaferParks	saferparks.org
UK Health and Safety Executive	hse.gov.uk
Outdoor Amusement Business Association	oaba.org

3.2 Brain Injury Association of America

The Brain Injury Association of America (BIAA) financed a study they conducted. The organization includes doctors, lawyers, and victims of brain injuries. They studied (16) brain injury cases attributed to amusement rides. The intent of the study considered whether brain injuries are a direct result of acceleration/deceleration forces. The study noted that the neurological injuries included bleeding of the brain and leaking of cerebrospinal fluid. The study equated the effects of the forces to that of brain injuries sustained because of "shaken baby syndrome." It also noted that the injuries may or may not be a direct cause of acceleration/deceleration.

3.3 CPSC National Electronic Injury Surveillance System (NEISS)

The Consumer Product Safety Commission issues annual ride injury reports for national statistics on fixed rides. Over 372 million people visit fixed-site parks each year and it is estimated that there are less than 2500 ride related injuries each year. The CPSC National Electronic Injury Surveillance System (NEISS) derives its information from hospital emergency room data for fixed-park injuries. The CPSC looked at industry injury trends for fixed-site rides from 1997 through 2001 and concluded that ride injury rates were statistically insignificant (2001).

3.4 American Association of Neurological Surgeons (AANS)

The assumption held by some advocates is that innovation in ride technology facilitates ride designs that are more thrilling, bigger and faster, therefore, they must have higher forces and that the industry is out of control, *"Pushing the limits on human endurance,"* (Hudson 2003). This misconception prompted the assembly of the AANS panel to research the safety of amusement ride systems. The AANS panel included specialists in biomechanical, engineering, epidemiology, neuroscience, neurotraumatology, and industry ride experts.

The objective of the panel was to determine if roller coasters present unreasonable risk, due to the impact of g-forces relative to the biomechanics associated with brain injuries. The panel reviewed reported cases of cranio-cerebral injury caused by roller coasters over a (38) year span, and looked at the magnitude of g-forces for contemporary rides systems, industry codes and standards, as well as industry data and statistics. They reached out to various industries that also deal with biomechanical factors related to g-forces to understand how they resolve into the body.

The AANS panel's research showed peak accelerations measured on roller coasters was 6 gs for 1 s, far below, and as much as 18 times lower than the brain injury threshold for healthy individuals. To this end, the panel summarized by reporting the risk of brain injury from roller coasters is associated more closely with the health condition or behavior of the rider than ride system dynamics.

By the end of the study, the AANS panel reviewed over (57) reported claims of medium to high impact ride related injuries. They concluded that while roller coasters pose a threat of injury to some people, the majority of the people are not at risk to suffer any injury, and the primary cause of injury was a result of a pre-existing condition. The pre-existing conditions that are at most risk were associated with pregnancy, heart condition, back and neck injuries. However, the most compelling outcome realized by the panel was that a federal agency would not be able to be as effective as the current system already in place.

3.5 Individual Tolerance to Sustained G-forces

The U.S. Navy and NASA research data concluded that when accelerations become too high or last for extended durations, blood flow to or from the brain is affected and may result in loss of peripheral vision, color vision, blackout and even loss of consciousness. The data showed that relatively low g-forces (3 gs) lasting for longer durations than 4–5 s could induce loss of consciousness, while higher g's (5 gs) at shorter durations of 2–3 s posed no threat to health. The military data also showed that the human body better tolerates forces that press down in contrast with lateral forces.

ASTM*i* F2291-17 limits vertical accelerations to 6 gs. The duration of the sustained forces during the actual ride experience is usually less than 3 s and are easily tolerated. Activities such as hopping, jumping, or collapsing into a chair produce higher g-forces for short durations in the range of 8–10 g's and are considered benign. Development of the F2291 standard defined the g-force limits and was reviewed by fourteen industry experts from around the world. The standard in its entirety resulted from the work of a global group of cross-industry experts from the medical, astrophysics, bio-dynamics, and biomechanical fields, whom came together to meet the need for a single, universally accepted design standard for amusement rides.

3.6 Characteristics Associated with Acceleration

Other contributing characteristics associated with acceleration deal with the fabrication of the equipment. Breakthroughs in major manufacturing techniques, material science and computer aided technology; all contribute to the reduction of forces for modern ride systems. Employing techniques that result in a smooth ride experience can greatly reduce forces previously induced by the ride dynamics. A report issued by Exponent Failure Analysis Associates (2003) evaluated data from 167 roller coasters from 1970–2003 and concluded that while the current day coaster is higher and travels at greater speeds, the g-forces are not as high as the more antiquated ride systems [9].

4 Discussion

Much attention centers around claims of brain injuries associated with high g-force rides resulting in a platform to drive legislation to regulate g-forces induced by roller coaster rides. The assumption held by some advocates is that innovation in ride technology facilitates ride designs that are bigger and faster, whereby, it is assumed the ride design must have higher forces and that the industry is out of control. This is not the case. While amusement rides have increased in height and speed in recent years, as discussed in Sect. 3, *Methods and Results*, many factors contribute to the design of a ride system.

In the absence of federal legislation, consensus standards are also known as customary law that are not directly enforceable in courts but nonetheless are commonly practiced and are widely accepted and have an impact on industry compliance. Due to the growing number and influence of such standards, customary law is quickly becoming a major source law. Standards continue to be the main driver regarding amusement industry compliance for design, operation, inspection and maintenance of ride systems.

ASTM*i* F24 standards committee for *Amusement Rides and Devices* is the cornerstone of the theme park industry. F24 is a world standard with committee members that span the globe with representation from (23) countries providing scientific and technical expertise which draws upon the greatest minds in the industry which include industry leaders, academia, government, and citizen representation. Among the family of F24 standards is ASTM*i* F2291, and it is the most comprehensive standard for the amusement industry.

5 Conclusions and Recommendations

The amusement industry draws on some of the greatest minds in the areas associated with biomechanical, biodynamic, and human factors regarding the application of g-forces. The industry relies heavily on the research data generated over the last eighty years by academia, the military and aerospace industries.

Understanding the value of standards and how to effectively influence industry standardization that one day may be adopted into legislation, makes for the greatest opportunity for success in the global market place. Technical experts, who are active participants in standards development, are the ones to shape issues that impact the industry.

As technical experts, the F24 committee needs to stay at forefront of standards development that integrates safety design and operation into amusement industry practices which has achieved normative status through its practice. The F24 committee comprises more than 1000 members and twice a year more than 300 of these members convene to discuss active standards development happening year round. This organization actively liaisons with committees responsible for parallel standards under the EuroNorms (EN) and International Standards Organization (ISO). Therefore, non-experts at the federal level trying to control and dictate requirements for industry that they do not understand is not beneficial for the amusement park industry.

The industry is complex and combines so many medical and engineering disciplines it is not reasonable to believe that politicians would have a better understanding of how accelerations and decelerations resolve into biomechanical attributes of the human body. At best, the government should look to industry experts to continue to drive industry standards and guidelines as innovation and technology develop. Where standards are based quantitative data and facts- not misconceptions. Albeit, "S*tandards influence practice- and practice influences law* [10].

6 Bibliography

1. American Safety Organization: Amusement ride accidents & news (2011). http://www.amusementsafety.org/safety_news_11.asp
2. American Society of Testing and Materials International (ASTM): F2291: Standards on amusement rides devices: Designation: F2291-17. Standard practice for design of amusement rides and devices, 8th edn., West Conshohocken, PA (2017)
3. American Society of Testing and Materials International (ASTM). F2137: Standard Practice for measuring the dynamic characteristics of amusement rides and devices. West Conshohocken, PA (2016)

4. Ammons, R.E.: Is the all-American amusement park safe? Thousands of visitors are injured every year at amusement parks, but the industry remains largely unregulated. Injured people lawsuits ask, how much fun is too much? Trail Mag. 40, 6, 30(5) (2004)
5. ASTM International Worldwide. Standards without borders: Global use of standards. www.astm.org/global/images/handbook_eng.pdf
6. ASTM International Worldwide, The handbook of standardization: A guide to understanding standards development today, The U.S. standards system. www.astm.org/global/images/handbook_eng.pdf
7. ASTM Standardization News: Promoting the value of standards. Promoting public-private collaboration in standards development (2016)
8. Braksiek, R.J., Roberts, D.J.: Amusement park injuries and deaths. Ann. Emerg. Med. **39**(1), 65–72 (2002)
9. Bothe, M.: Trends in environmental policy and law. IUCN Environmental Policy and Law Paper No. 15, p. 392. Gland (1980)
10. Collins, D.: Researchers: Roller Coasters are Safe, January 2003. http://www.cbsnews.com/news/researchers-roller-coasters-are-safe
11. Consumer Product Safety Commission: National Electronic Injury Surveillance System (NEISS), Washington, DC (2001)
12. Cooke, C.C.W.: Ed Markey's Peculiar Crusade: his unhealthy obsession with amusement park Safety. National Review online, 9 February 2013. http://www.nationalreview.com/articles/340033/ed-markey-s-peculiar-crusade-charles-c-w-cooke
13. Eldridge, L.D., Northrupt, S.E.: Effects of acceleration. In: O'Brien, D.M. (ed.) US Air Force Flight Surgeon Manual (1995). Chap. 4:1–11. http://www.sam.brooks.af.mil
14. Fackler, K.: Amusement ride accidents. Saferparks (2009). www.saferparks.org
15. Gilbert, S.: When brain trauma is at the other end of the thrill ride. The New York Times, 25 June 2002. http://www.nytimes.com/2002/06/25/health/when-brain-trauma-is-at-the-other-end-of-the-thrill-ride.html?pagewanted=all&src=pm
16. Hudson, T.H.: A new world standard for amusement rides. ASTM Standardization News, p. 4 (2003)
17. Hudson, T.H.: Safer by design/technology in amusements. NSC. Injury Insights. Itasca, IL, June 2003
18. International Association of Amusement Parks and Attractions (IAAPA): Amusement ride safety. Safety by the numbers (2014). http://www.iaapa.org/safety-and-advocacy/safety/amusement-ride-safety
19. Munsey, C.: Frisky, but more risky. Am. Psychol. Assoc. **37**(7), 40 (2006)
20. National Safety Council: Fixed-Site Amusement Ride Injury Survey. Alexandra, VA (2015)
21. Smith, D.H., Meaney, D.F.: Roller coasters, g-forces, and brain trauma: on the wrong track? NSC: Injury Insights, Itasca, IL (2003)
22. Spark, N.T. (n.d.): The story of John Paul Stapp: the fastest man on earth. Wings/Airpower Magizine. http://www.ejectionsite.com/stapp.htm
23. Stenzler, P.M.: A Retrospective Study of Amusement Ride Restraint and Containment Systems: Identifying Design Challenges for Statistically Rare Anthropometric Cases. ODU, Norfolk, VA (2016)

24. Stenzler, P.M.: Consensus Standards Development Influencing Legislation: In the Absence of International Environmental law. NEC, Henniker (2011)
25. Varney, N.R.: Brain Injury Association completes review of the correlation between brain injury and roller coaster rides. NSC. Injury Insights. Itasca, IL, June 2003
26. Woodcock, K.: Amusement ride injury data in the United States. Saf. Sci. **62,** 466–474 (2014)

References

1. International Association of Amusement Parks and Attractions
2. Smith, D.H., Meaney, D.F.: Roller coasters, g-forces, and brain trauma: on the wrong track? NSC: Injury Insights. Itasca, IL (2003)
3. National Safety Council (2015)
4. Woodcock, K.: Amusement ride injury data in the United States. Safety Sci. **62**, 466–474 (2014)
5. ASTM International: Standard Practice for Design of Amusement Rides and Devices F2291-17, West Conshohocken, PA (2017)
6. ASTM International Worldwide: The handbook of standardization: a guide to understanding standards development today, The U.S. standards system. www.astm.org/global/images/handbook_eng.pdf
7. ASTM Standardization News: Promoting the value of standards. Promoting public-private collaboration in standards development (2016)
8. Cooke, C.C.W.: Ed Markey's Peculiar Crusade: His unhealthy obsession with amusement park safety, 9 February 2013. National Review online, http://www.nationalreview.com/articles/340033/ed-markey-s-peculiar-crusade-charles-c-w-cooke
9. Collins, D.: Researchers: Roller Coasters are Safe, January 2003. http://www.cbsnews.com/news/researchers-roller-coasters-are-safe
10. Bothe, M.: Trends in environmental policy and law. IUCN Environmental Policy and Law Paper No. 15, Gland P. 392. (1980)

Unobtrusive Bioanalytics for Impact–Related Sport Activities

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Abstract. A preliminary study was performed to determine the potential of an image analysis methodology to detect breathing parameters using a smart mouthguard. The smart mouthguard would be enabled with a light-emitting diode (LED) to transfer information regarding relevant breathing frequencies. The detection accuracies of Viola-Jones based algorithms were determined using a video stream of a virtual LED enabled mouthguard. A good accuracy for the detection of the LED enabled mouthguard was found and the simulated breathing frequency was correctly predicted using the proposed algorithm. The potential to measure breathing parameters using the presented smart mouthguard methodology might lead to new ways of injury prevention and performance management.

Keywords: In-body wearables · Physical activity · Human factors · Respiration Prevention · Design engineering

1 Introduction

Contact Sports

As athletic participation continues to increase around the world, the need for mouthguards will continue to climb. It has been estimated that over 40 million mouthguards are sold annually in the US alone [1]. This number is expected to grow proportionally with the increase of contact sport athletes and the surge of associations that make wearing a mouthguard compulsory. There is a strong need within the contact sports community to show that these sports can be played safely, as contact sports now include some of the fastest growing sports in the world.

Breathing and Injury

Research has shown that (contact) injury rate is higher towards the end of a sports match [2], indicating an obvious link with fatigue. The suggested relationship between injury and fatigue is supported by findings that the majority of rugby league injuries occur during tackles [3] and in the second half of matches [4] when players are more fatigued. The risk of injury seems to increase when contact-sport athletes fatigue during the game. Their decision making process begins to be compromised, as they get more fatigued [5]. It has been proposed that exercise tolerance in highly motivated subjects is ultimately limited by the perception of effort [6]. This shows that muscle fatigue alone can't explain

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why a physical activity is consciously terminated [7]. These findings provide further support to the psychobiological model of exercise tolerance and performance. Therefore, accurate and obtrusive information of physical exertion can greatly help in injury and performance management. Physical exertion has been shown to be the primary cause for exhaustion and has a strong physiological association with breathing parameters (e.g. respiratory frequency) [6]. Changes in ventilation will also directly alter the perception of exertion, while this is not the case with other often measured physiological parameters, such as heart rate [8, 9].

The mouthguard provides the ideal system for unobtrusive tracking of these important breathing parameters. Other systems that track respiratory rate often require the athlete to wear additional devices, which often translate a low adherence to these new technologies. Chest bands are probably the most used approach to pick-up respiratory rate information, but the chest band design provides limited suitability across all contact sports athletes. The belt can easily be displaced or damaged during direct contact. It would not provide a viable option for close contact sports, such as mixed martial arts, and it might even be a safety risk if there is any chance of entanglement. The same applies to more integrated systems that might have the measurement devices embedded within the athlete's clothing [10]. Although, it does create a more discreet design approach, it cannot rely on the assumption that the fabric would only move due to respiration. Clothing is grabbed and pulled in many contact-sports, both intentionally and un-intentionally. More clinically orientated devices that can detect breathing rate using electrocardiogram (ECG) and photoplethysmogram (PPG) signals [11] provide high-quality measurements. However, these kind of technologies are not fit for purpose for application on the sports field. A more user-friendly technique would be to remotely monitor the athlete's breathing through non-contact methodologies [12]. This would deliver a very user-friendly approach, but it suffers from a limited operation range and strict environment requirements in terms generating useful results. Although, the presented "state-of-the-art" non-contact monitoring solution [12] uses frequency modulated carrier waves and localization techniques to separate different sources of motion in the environment it will be difficult to reach meaningful detection levels in real-world complex scenarios.

The ideal approach would be to use the unobtrusive nature of a (smart) mouthguard with the remote monitoring capabilities of an imaging analysis methodology. The application of feedback through image analysis is widely adopted by trainers and athletes. It has clear benefits to the user who wants to improve their technique to reduce unwanted injuries. It can also be applied by the coach, as a training tool, to create a competitive advantage [13]. Combining analytical signal processing for physiological data with an in-body tracking system that is embedded in an already well-established piece of sport gear provides a minimally obtrusive solution for monitoring purposes. An interesting way to convey information between the mouthguard and the image recording equipment would be by the use of a light emitting source. A light-emitting diode (LED) embedded in the mouthguard would provide a low-cost and low-energy solution for data transfer.

The objective of this study is to compare the mouth detection accuracy between several image analysis algorithms in order to determine which algorithm would be the most suitable for estimating breathing frequency based on a novel LED enabled smart mouthguard. The detection algorithms will be assessed using simulated data, to provide an absolute reference value for the comparison between algorithms. The most accurate detection algorithm will be used to subsequently detect the virtual light (LED enabled mouthguard) within the mouth. A final comparison will then be made between the simulated and detected breathing frequency.

2 Methods

2.1 Smart Mouthguard

The smart mouthguard consist of a circuitry that enables acoustic signals to be processed and outputted through a LED. A high brightness LED can generate a signal that can be detected even within a well-lit environment. The LED can be turned “on” or “off” in sync with the respiratory signal that is obtained by an acoustic sensor. Embedding this whole system into a mouthguard creates a potentially novel method for transferring respiratory data.

An acoustic sensor placed in the oral cavity provides a data collection technique that generates a good signal-to-noise ratio, due to its close proximity to the source of interest. It benefits from the fact that the mouth will act as insulator for external background and environmental noise. The system consists of a small lithium ion battery to power a printed circuit board that is LED enabled and connected to an acoustic sensor (Fig. 1 shows an example prototype). The LED-enabled smart mouthguard delivers a visual cue of when the participant is inhaling or exhaling (light is “on”) and the transition points between them (light is “off”).

Fig. 1. Prototype of the electronics embedded in the mouthguard.

The workings of this prototype were used to produce a stack of images that contained a simulated light source near the center of the mouth. The simulated light in the images represents the LED within the smart mouthguard, from a virtual perspective. The images were combined to create a video stream in which the “on” and “off” timings of the LED were exactly known and allowed for a direct comparison with the outcomes of a detection algorithm.

2.2 Video Stream

Data was recorded using the Facetime HD camera of an Apple Macbook Pro (Retina, 13-in., 2013). The video stream consisted of 511 frames, which produced a video of 25 s. A recording was taken of a subject's head moving sideways, up and down, as well as rotating around a longitudinal and horizontal axis. The range of motion was large (>90°) in order to create a challenging video for the detection algorithm. The mouth was manually labelled for all frames to provide an accurate reference value for comparison between the different versions. A simulated LED was generated by placing a small light blue box in the middle of the mouth in some of the frames. The virtual LED was placed within the video stream in such a way that it would produce a simulated breathing frequency of 0.1 Hz.

2.3 Image Analysis

The aim of the image analysis algorithm is two-fold. The first step is to detect the location of the mouth within a frame (Fig. 2). This optimization step helps with the subsequent identification of the LED, by reducing the search area. The detection of the mouth also helps to reduce the incorrect detection of light sources that do not represent the LED-enabled mouthguard. The aim was to have the mouth accurately detected, ideally with an accuracy of $> 95\%$, before the subsequent detection of the LED would be considered.

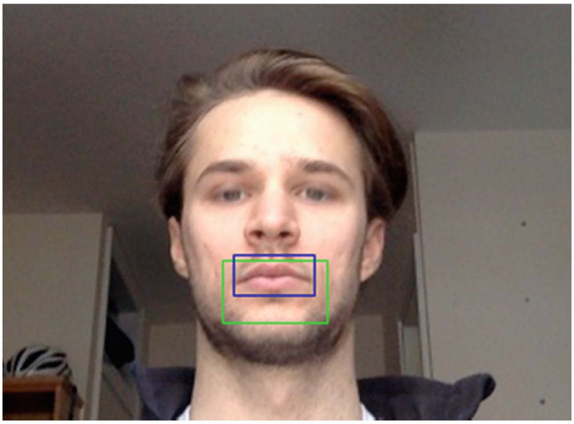

Fig. 2. A single frame of the video stream showing the manually labeled mouth (small dark blue box) and the area that was identified by a detection algorithm to contain the mouth (larger green box).

The first algorithm relied on detecting the users mouth within the frame of a video using the Viola-Jones (VJ) method [14]. This method could be implemented in real-time, which is essential for the application of the smart mouthguard. The first version (vj1.0) detects every face within each frame. Then the algorithm searches the area of each face to detect a mouth within that face. Additional versions (vj1.1–2) were designed that used the location of the mouth in the previous frame to locate the mouth in the current frame. Thus, the algorithm searches an area around the previous mouth's location. This approach should speed up the detection process, as the algorithm is searching only a fraction of the total area available. The next versions (vj1.3–4) were developed to prevent the algorithm from getting stuck on e.g. an eye. The VJ method can easily perceive an eye to be a mouth, due to their similar shape. Therefore, the code was optimized to better predict which of the features that are identified as a mouth in the VJ method is actually the mouth. The algorithm relies on the fact that the VJ method should find both eyes and the mouth, we just need a way to determine which of those found features is the actual mouth. The first technique (vj1.3) uses the fact that most often the actual mouth will be the lowest feature found in the frame, so the algorithm saves the feature lowest in the frame as the mouth. The second technique (vj1.4) uses the fact that the distance between the eyes will be shorter than the distance between the mouth and either eye. The second main version (vj2.0–1) of the algorithm does change the base set-up for the mouth detection. Instead of sending the entire video for analysis to a separate script the main script now creates a separate class for each individual frame and then performs the analysis on that frame. This should lead to an increase in time taken for the entire script to run, but it makes the algorithm more suitable to run in real time.

The third versions (vj3.0–4) implement a Kalman filter (KF) to better track the mouth within the frame. Version vj3.0 uses the actual mouth and face locations as the measurement input for the KF. This version was only implemented to ensure the KF works properly and therefore does not provide any meaningful results in terms of accuracy. The vj3.1 runs the algorithm with KF, with vj3.2 providing an additional correction to select the mouth that is located closest to the bottom of the image if multiple mouths are detected. The next version (vj3.3) uses the KF's predicted location of the mouth to determine which mouth is most likely to be the correct mouth. The last version (vj4.1)

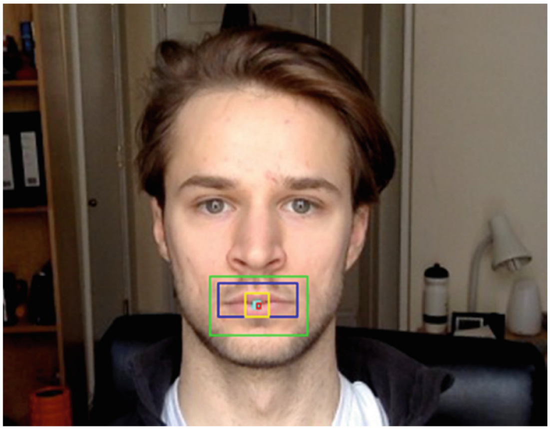

Fig. 3. A single frame of the video stream with the simulated LED (small light blue square in the middle of the mouth). It shows the manually labeled mouth (dark blue box), mouth area detected by algorithm (larger green box), manually labelled LED (yellow squared box) and detected LED (small red square box).

searches the area of the detected mouth for a blue LED and uses that information to more accurately predict the mouth's actual location (Fig. 3).

2.4 Simulated Respiratory Rate Detection

The first step consisted of the detection of the light from the simulated LED. To detect the light a mask of the detected mouth is taken, using the expected colour range of the light. Then the contours of this mask are found, if there exists a contour within the mask the light is considered to be successfully detected. The mask is created by checking each pixel value inside the chosen mask is within the lower and upper colour boundaries. A digital signal is created by recording whether a light was detected/on. If the light was detected a 1 is assigned to that frame, it not then a 0 is recorded. The digital signal was further processed in order to reduce the noise in the signal.

The signal processing consisted or determining the parameters for the Kaiser window method [15] using the desired attenuation in the stop band, as well as the video sample rate. This windowing technique is used to design a suitable linear-phase filter for the signal. Then a Blackman low pass finite impulse response filter was used to filter out the high frequency components of the signal. The signal is then further processed by flooring every component of the signal below 0.5 to 0 and ceiling every component of the signal above 0.5 to 1. This generated a binary time-series signal. Finally, the signal was adjusted so that if the light was "off" for <15 frames then it was assumed that the light was lost, but "on". The signal was corrected in this case by assigning a value of 1 for all frames identified.

2.5 Data Analysis

The accuracy is determined by comparing the coordinates of the top-left and bottom-right corners of the detected object (*detected_x*) and the actual (manually recorded) object (*actual_x*). The Eqs. 1–3 demonstrates how the score for each version is determined.

$$Score = \frac{1}{N} \sum\nolimits_{i=1}^{N} a_i \tag{1}$$

$$a_i = \begin{cases} 0 & if\ actual\ coordinate = 0 \\ \frac{1}{4} \sum\nolimits_{j=1}^{4} b_j & otherwise \end{cases} \tag{2}$$

$$b_j = 1 - \frac{\left| detected\ x_j - actual\ x_j \right|}{actual\ x_j} \tag{3}$$

With N is total number of frames where the object was visible, i is the frame number, j is the indexes for the coordinates of the top-left and bottom-right corners of the desired object.

All data was processed and analyzed using Python (Python 3.6.2, Python Software Foundation, www.python.org). The algorithms were developed in Python and module OpenCV 3.3.0 was used to implement the VJ method, in addition to the python modules Numpy 1.13.1 and SciPy 0.19.1. All algorithms were implemented in the Pycharm Community Edition (www.jetbrains.com/pycharm/).

3 Results

The results for each of the algorithms described in the methods section are provided in Table 1. It can be seen that vj1.2–3 yield the lowest time per frame, while vj4.1 generates the best detection accuracy.

Table 1. The table contains data for each detection algorithm. The first column shows the different algorithms used to detect the mouth. The second column indicates the time it took to process a frame. The final column shows the detection accuracy. The vj3.0 – KF does not contain values, as it was a test version to check the KF was working correctly. *vj = Viola-Jones and KF = Kalman Filter*

Version	Time per frame (ms)	Detection accuracy (%)
vj1.0	89.2	33.5
vj1.1	73.3	33.3
vj1.2	31.9	68.5
vj1.3	31.9	64.4
vj1.4	33.9	62.0
vj2.0	111.6	88.3
vj2.1	42.5	90.8
vj3.0 – KF		
vj3.1 – KF	114.6	93.5
vj3.2 – KF	47.5	87.8
vj3.3 – KF	50	89.2
vj4.1 – KF	45.8	95.9

The accuracy of the algorithm (vj4.1) for detecting the light was 79.1%. The signal processing predicted a breathing frequency of 0.125 Hz, as the original simulated breathing frequency was set at 0.1 Hz.

4 Discussion

The results show that a high accuracy can be achieved using a Viola-Jones (VJ) method combined with a Kalman filter alongside basic signal processing techniques to detect the mouth and virtual LED. The best performing algorithm (vj4.1) correctly determines the simulated breathing frequency. These outcomes are promising and provide a new way to assess physical performance.

Unlike pedometer and accelerometer devices this smart mouthguard makes direct physiological system measurements to determine the perceived intensity of physical performance. In addition, breathing monitoring is perfect to measure recovery and provide an estimate of overall fitness. Respiratory markers can also be used to inform the sporting community regarding training intensity and risks. The metrics can aid contact sport athletes in understanding their performance and assist in personalizing their training regime without the requirement to wear any additional gear. It can also be used to make decisions regarding the potential injury risk athletes face during training or competition. Breathing parameters can be used to measure changes in perceived exertion allowing the athlete to monitor and check how they train or play the game. It was shown that rugby league players with low speed and maximal aerobic power are at an increased risk of injury [16]. This highlights the need to look not just at impact, but also physiological performance.

The integration of the LED into the mouthguard provides a low-cost and low-energy solution for detection. Depending on the specification of the light source (e.g. brightness) and camera (e.g. focus, sample frequency and resolution), different levels of detection can be obtained on the sports field. The image analysis technique is further affected by the requirement of an unobstructed view. However, the reduction of cost and the ever-increasing quality of cameras has led to the pervasive nature of image capture. Most wearable electronic devices, such as smart phones, already come with a high-spec camera. These devices can easily be leveraged to perform the required image analysis within the sporting arena. More professional settings will have dedicated cameras that can be utilized for this purpose. An array of LEDs can be integrated to optimize detection rate at different view angles and apertures of the mouth.

This principal function of the mouthguard to prevent injury of the teeth should not be impeded by the integration of electronics. Mechanical testing needs to be performed to provide information on how the electronics can be safely integrated into such a system without increasing the risk of damage to the athlete.

The presented work in this study is based on a relative small data set, which limits the external validity of the results. The video was recorded with the head moving in many directions, but it does not capture all the complexities of a field recording. However, these initial results show that the approach described could provide a potential viable way of detecting respiratory rate on the sports field. Further work will consist of validating the approach during field measurements and will also include the quantification of amplitude in addition to breathing frequency.

Currently, no product exists for the contact-sport market that allows for reliable and comfortable performance measurements and which can greatly increase safe participation of athletes in a wide range of sports without the need for recalibration. The smart mouthguard makes direct physiological system measurements to determine the perceived intensity of exercise. The potential promise to prevent injuries and promote safe (contact) participation will have a positive benefit on the lifelong health of those participating in these sports.

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References

1. Brett, D.: Mouthguard Evolution, 27 Feb 2003. http://www.dentistryiq.com/articles/dem/print/volume-8/issue-1/materials/mouthguard-evolution.html
2. Nicholas, B., Mike Ian, L., Wayne, V., James Craig, B., Clint, R., den Steve, H., et al.: Mechanisms and factors associated with tackle-related injuries in South African youth rugby union players. Am. J. Sports Med. **45**, 278–285 (2016)
3. Gabbett, T.J.: Incidence of injury in semi-professional rugby league players. Br. J. Sports Med. **37**, 36–44 (2003)
4. Gabbett, T.J.: Incidence, site, and nature of injuries in amateur rugby league over three consecutive seasons. Br. J. Sports Med. **34**, 98–103 (2000)
5. Borotikar, B.S., Newcomer, R., Koppes, R., McLean, S.G.: Combined effects of fatigue and decision making on female lower limb landing postures: central and peripheral contributions to ACL injury risk. Clin. Biomech. (Bristol, Avon) **23**, 81–92 (2008)
6. Marcora, S.M., Staiano, W.: The limit to exercise tolerance in humans: mind over muscle? Eur. J. Appl. Physiol. **109**, 763–770 (2010)
7. Enoka, R.M., Duchateau, J.: Muscle fatigue: what, why and how it influences muscle function. J. Physiol. **586**, 11–23 (2008)
8. Robertson, R.J.: Central signals of perceived exertion during dynamic exercise. Med. Sci. Sports Exerc. **14**, 390–396 (1982)
9. O'Sullivan, S.B.: Perceived exertion. a review. Phys. Ther. **64**, 343–346 (1984)
10. Zhao, Z., Yan, C., Liu, Z., Fu, X., Peng, L.M., Hu, Y., et al.: Machine-washable textile triboelectric nanogenerators for effective human respiratory monitoring through loom weaving of metallic yarns. Adv. Mater. **28**, 10267–10274 (2016)
11. Charlton, P.H., Bonnici, T., Tarassenko, L., Alastruey, J., Clifton, D.A., Beale, R., et al.: Extraction of respiratory signals from the electrocardiogram and photoplethysmogram: technical and physiological determinants. Physiol. Meas. **38**, 669 (2017)
12. Adib, F., Mao, H., Kabelac, Z., Katabi, D., Miller, R.C.: Smart homes that monitor breathing and heart rate. In: Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems, pp. 837–846 (2015)
13. Liebermann, D.G., Katz, L., Hughes, M.D., Bartlett, R.M., McClements, J., Franks, I.M.: Advances in the application of information technology to sport performance. J. Sports Sci. **20**, 755–769 (2002)
14. Viola, P., Jones, M.: Rapid object detection using a boosted cascade of simple features. In: Proceedings of the 2001 IEEE Computer Society Conference on Computer Vision and Pattern Recognition, CVPR 2001, vol. I (2001)
15. Kaiser, J., Schafer, R.: On the use of the I < inf > 0 </inf > -sinh window for spectrum analysis. IEEE Trans. Acoust. Speech Sign. Process. **28**, 105–107 (1980)
16. Gabbett, T.J., Domrow, N.: Risk factors for injury in subelite rugby league players. Am. J. Sports Med. **33**, 428–434 (2005)

A Test Setting to Enhance Bobsled Performance at Start Phase

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Abstract. This paper focuses on a test setting that could be used to enhance performance of bobsleigh teams. The collaboration of the teams plays an important role to maximize the performance during bobsleigh runs. We introduce a method to log forces at the start of the run. The setting is validated for 10 runs of nine pilot and brakeman duos. Runs with synchronized force peaks exhibit slight improvements in start speed (0.07 m/s) and start time (52 ms). These improvements are not significant. We provide recommendations for an improved test setting that could be used to collect data to retrieve those factors that mostly influence athletes' performance in starting bobsleigh runs.

Keywords: Bobsleigh · Force analysis · Starting speed optimization Synchronization

1 Introduction

In bobsleigh, a team of two or four athletes descend an ice track in the fastest possible way. The athletes firstly push the bobsled to a maximal speed and after jumping in, they slide down to the finish [1]. Previous research showed the importance of vehicle parameters as aerodynamics, sliding resistance, weight distribution and inclination of the steering axis. Bobsled adjustments are tuned in function of athletes' subjective feedback, without support of scientific examination to establish improved quality of performance [2, 3].

Latest wind-tunnel infrastructure allows to assess the aerodynamic flow around sport equipment at highly realistic temporal and spatial resolution. State of the art algorithms for big data analysis and data driven models to extract those factors that mostly influence performance, propose models that optimize performance. The elaboration of an aerodynamic model combined with optimizing kinematic parameters of the athletes should maximize the performance in bobsleigh.

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The athletes themselves should optimize their track. A small advantage at the start of the race, can lead to up to three times bigger time gains at the finish, due to the constant acceleration during the descent [4–6]. Therefore, the start procedure is crucial. Literature concerning improving the start velocity by analyzing the athletes is limited. The official bobsleigh start can be split into two phases. The front runner, also called pilot, and rear runner, also called brakeman, give an initial push to the sled, followed by a 15 m track, called the ‘push-off stretch’. A 50 m track part, where athletes need to quickly jump into the sled, follows this first part. Run time in bobsleigh competitions is measured from the start of this second part [1]. This study focuses on the first start phase and considers the first five meters of the ‘push-off stretch’ for a two-person bobsled.

Evaluation of the running pattern during the start [7] and detailed analysis between various bobsled teams during competition [8] indicate differences in performance for diverse start procedures. Using video analysis, pilot and brakeman’s movement patterns can be described. Best movement patterns are separately obtained for pilot and brakeman based on best starting time. Kinematic parameters as step length and frequency and foot contact time as well as trunk, knee and elbow angles during the running pattern are investigated to conclude optimal posture and movement during the start procedure [6].

In this experiment, synchronization of both athletes will be considered instead of individual movement patterns. The *synchronization offorce peaks* for pilot and brakeman can have considerable opportunities while pushing the bobsled. The simultaneity of movements has efficient applications for ameliorated performances in other sports as rowing [9, 10] and for tug-of-war athletes in synchronous force production [11].

This article analyses force distribution of pilot and brakeman in relation to *speed and time*. Therefore, a dummy bobsled test setup is developed to simulate the initial start phase. Lee [12] developed a similar bobsled model to exert force and speed, without considering synchronization analysis of pilot and brakeman. This study describes the proof of concept with the aim to elicit potential benefits of an aerodynamic bobsled model in combination with synchronization of movement patterns of pilot and brakeman athletes.

2 Materials and Methods

2.1 Participants

18 healthy, non-pathological subjects who practice sports regularly were included for the experiment. 14 male and 4 female subjects, ranging in age between 19 and 23 years, volunteered to participate in this experiment. They were assigned to the same experimental task. There were no dropouts during these sessions.

2.2 Test Setup

A 12-m wooden track was constructed with longitudinal delimiters on the right side to keep the sled on track on standard wheels, of the shelf available. Rails were only added on the right side as deviations will only occur in that direction, due to the pushing bar placed on the left side. This rail positioning prevents hindering the running subjects. Three microswitches were positioned on the rail to calculate time and speed by touching them when pushing the sled. On the wooden track, start and finish lines are marked, respectively at 0 m and 5 m. The remainder area was used to brake and for safety.

An *aluminum frame* (Fig. 1) was built along geometrical dimensions of a two-person bobsled and endowed with ballast to achieve realistic weight. Dimensions of the sled comply with the international rules of the IBSF (International Bobsleigh and Skeleton Federation), which include limits for dimensions as well as weight of bobsleds. The frame is supplemented with six wheels on each side. Two handles at the back and one push rod in front are provided so that two subjects can push the bobsled.

Fig. 1. Dummy bobsled test setup on 12 m wooden track. The sled consists of one push rod for the pilot and two handle bars for the brakeman. Weight and dimensions were adjusted to IBSF rules.

Button *load cells* (CZL204E) were implemented between push bars and frame to measure the used force at three positions, namely at the left and right handles for the brakeman and at the push rod for the pilot. The load cells have a capacity of 200 kg and a precision of 0.2%. Data of the force sensors was amplified using a HX711 module and wireless transferred using Arduino Feather LoRa and HC-12 modules. Real time data was streamed at 10 Hz.

2.3 Pilot and Brakeman Experiments

The load cells were calibrated using several weights, ranging from 3.29 kg to 7.21 kg, placed on the handle bars and front push rod at three positions: in the middle and at the two outer pushing positions. This measurement was repeated three times to verify repeatability. The procedure was repeated with the sled positioned under three different angles with the floor, respectively 25°, 41° and 52°, to simulate the subjects' push at a specific angle instead of in horizontal direction (Fig. 2). Dynamic force calibration was controlled with the Vernier Dual-Range force sensor and software. This sensor has a range of 50 N and resolution of 0.05 N. This calibration step gives an indication about the efficiency for dynamic changing forces.

After calibration, measured force was logged as function of time as well for the pilot as for the brakeman. For the brakeman, the sum of forces on both handle sides was calculated. A collection of logs was stored to retrieve optimal time-force diagrams. Hence, the influence of both athletes' forces on time and speed can be investigated.

Participants were randomly divided in nine duos, each duo of the same gender. Subjects were instructed to push the sled as fast as possible to the finish line. Each duo performed 15 runs, whereof last 10 runs were included for the analysis.

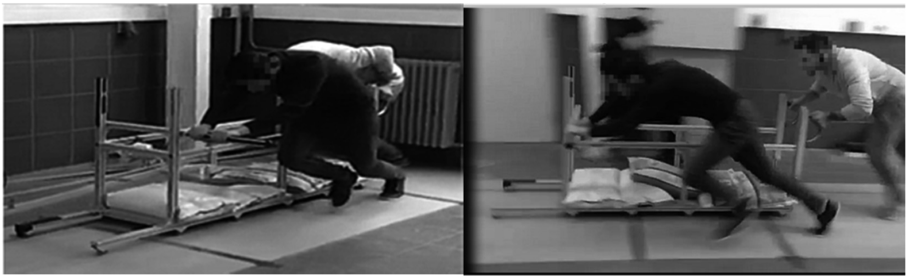

Fig. 2. Left: Start position of the pilot and brakeman. Right: Finish line after 5 m. Push angle during the run of both subjects is visible in this image.

2.4 Analysis

For all runs, a force-time diagram was obtained for pilot and brakeman (Fig. 3). The fluctuations of the forces inter and intra duos were mapped to allow visual interpretation. Force outcomes were compared with Newton's second law (1) to estimate accuracy and resolution. Speed after 5 m was measured through onsets of micro-switches. Newton's second law, $F = m.a$, was used to model acceleration from forces and end-speed by integration:

$$v = \int \frac{F.t}{m} dt. \quad (1)$$

Here v is the estimated end speed, F the measured force of pilot and brakeman, t the time over the 5-m run and m the mass of the bobsled. The estimated speed, i.e. area below the total $F(t)$ function divided by the mass, should be equal to the measured end speed.

To evaluate the effect of synchronization on speed and time, synchronization was assessed via time differences between initial force peaks of both athletes (Fig. 3). A run was considered synchronous when time difference between both athletes was not detected by the sampling method, in this case, maximally 100 ms. Higher time differences are considered as asynchronous runs.

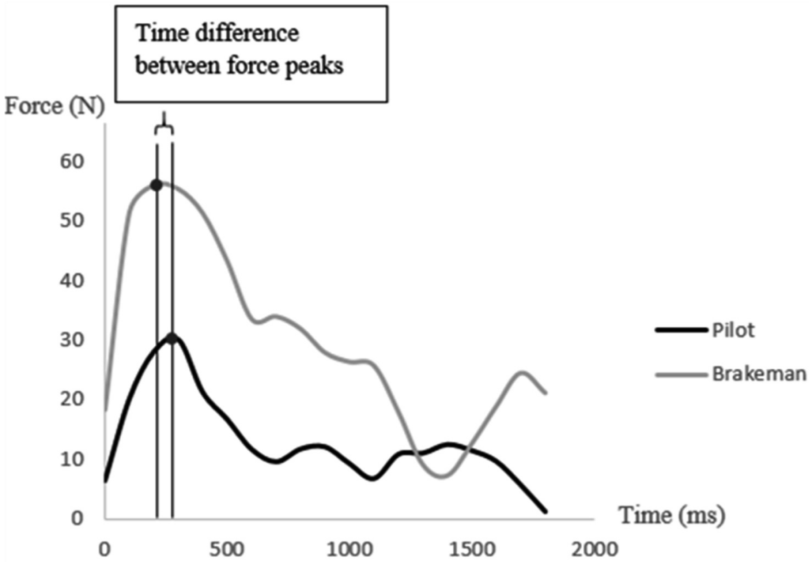

Fig. 3. Graphical representation of *force* as function of *time*. The brakeman curve consists of the sum of forces of the left and right handle bar. First force peak is indicated for both subjects (*dots*) and *time difference between both peaks* is calculated to determine synchronization of the run.

Furthermore, time over five meters and speed after five meters was added in the processing sheet. Relations between time and synchronization on the one hand and speed and synchronization on the other hand were studied using independent samples tests. The hypothesis is that synchronous runs provide faster time and increased speed at the end of the start procedure (5-m finish).

3 Results

3.1 Calibration

Load cells were calibrated against specific fixed weights at several positions at the three push bars. The bobsled was placed upright (90°) and under three different angles. Every combination position-weight calibration was repeated six times. Load cell outcomes were compared with effective weights. Root mean square error (RMSE) was calculated for the three sensors, for repeated measurements (Table 1). Average RMSE is 1.25 kg, which seems a feasible deviation for our application.

As the subjects were not pushing in the middle of handle bars, exerted forces outside center point of the sensors deviates from the calibrated value. Therefore, the same weights were placed at outer extreme points of the three bars to indicate the influence thereof on the outcome values. The ratio outside/center and inside/center was comparable for all three sensors, respectively 1.28 ± 0.12 for outside/center and 0.74 ± 0.23 for inside/center ratios.

Table 1. RMSE for the three sensors for several bobsled angles during the calibration.

	RMSE (kg)		
Angle bobsled (°)	Front sensor	Back sensor right	Back sensor left
90	1.24	4.02	0.19
25	1.10	1.17	0.93
41	1.92	0.68	0.66
52	2.03	0.60	0.43

In a second calibration step, the load cells were compared with a Vernier sensor, to prove their reliability during dynamic forces up to 50 N pressure force. A small systematic error is visible in the Fig. 4.

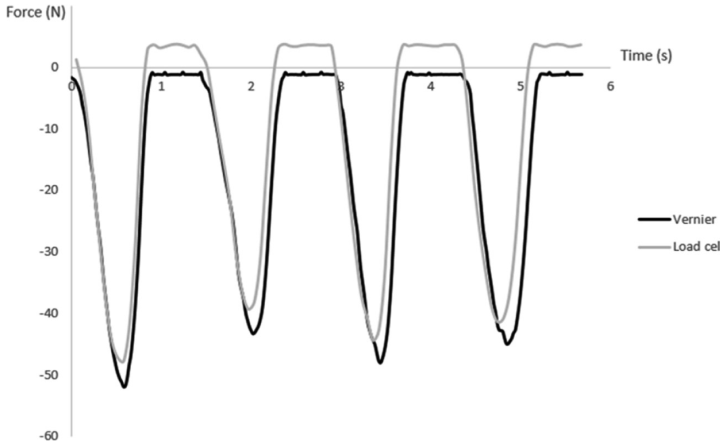

Fig. 4. Graphical representation of comparison between *load cell* and the *Vernier* sensor. Four dynamic push forces are exerted on the push rod.

Speed measured with microswitches was compared by the estimates via Newton's second law (Fig. 5). The estimated speed is systematically higher than the measured speed. This can be explained by friction and roll resistance. Minimal and maximal speed estimates, considering potential error on force measurements, are shown in Fig. 5. Only two measurements slightly exceed the extreme boundaries. This step confirms the correctness of the results.

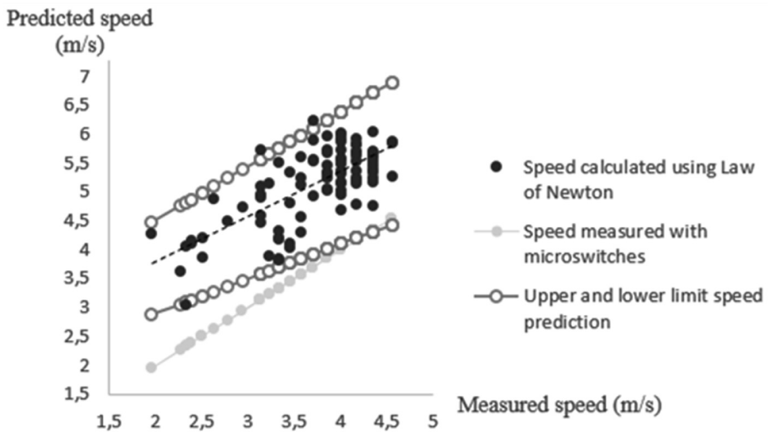

Fig. 5. Speed estimations and measured speed. The *estimated speed* is higher than the *measured speed*, but within the upper and lower bounds, considering the accuracy of the force measurements.

3.2 Pilot Brakeman Experiments

Of all 90 runs, 41 were classified as synchronous. Graphical inspection (Fig. 3) of pilot and brakeman's force distribution for all runs of nine duos indicated little improvements in time between synchronous and asynchronous runs. Runs with synchronized force peaks give slightly faster end speeds (0.07 m/s) and shorter start time (52 ms), but these differences are not significant ($p = 0.6$).

4 Discussion

An experimental setup was presented to investigate the influence of synchronization, between the pilot and the brakeman in a two-person bobsleigh team, on starting time and speed at start. Firstly, the reliability of force and speed measured values was checked using Newton's second law. From the comparison between measured speed and estimated speed, we can conclude that our setup gives realistic values. Except for two values, all measurements fit in between the outer bandwidths, considering potential inaccuracies. All duos were tested subsequently. The friction in the first 10 runs of the first duo is noticeable smaller than in other duos, which can be declared by the worn of wheels observed after a few runs. The differences between the estimated and the measured speed can thus be declared by friction losses.

4.1 Limitations

The main limitations of this experiment were small sample size, limited space at the test location and wear of the used material. In particular, subjects had to slow down the moment they passed the 5-m mark. They had to exert counter force to slow down the sled over the remaining area to zero speed. Although no significant effect of synchronization on start performance was observed, first results show auspicious results, which should be validated using an improved setup.

Firstly, this was a *small-scale experiment*. With only nine duos participating, firm conclusions were hard to draw. This research could only give us an indication on the influence of synchronization. More general parameters of the force distribution during starting phase could reveal other patterns. To that end, test setting should be further optimized such that upper and lower bound speed estimates, grey circles in Fig. 5, coincide with measured speed.

The *location* has the disadvantage that some of the subjects could not push their maximal effort due to the limited space, so that subjects had to temper their maximum force to ensure that the bobsled could be stopped on time. Additionally, the *mechanism to register time and speed* must be optimized. When the sled slightly deviated from the rail, microswitches were not activated and time and speed could not be calculated. Heighten the rail could solve this problem but will also cause more friction. A rail based solution should be considered, e.g. to simulate real bobsled track where the bars of the sled slither in grooves, to keep the sled in the right direction. This could also tackle the problem of *worn wheels*.

Lastly, within this study, there was *no standardization* for the start procedure. Participants were each run free to choose their own preferable start position, which could lead to different push offs and a difference in time or speed. Subjects could choose whether they were pilot or brakeman at the start of the trial. Also, no indication was given about the ideal posture during a bobsled start. The influence of these factors was not examined in the study.

4.2 Future Work

Some participants indicated that they were not able to go to their maximal effort. They were afraid they could not slow down the sled on time. In future studies, participants should go to their maximal capacity during the initial start, without considering the side effects, for firm test data. By relocating this experiment, the start could be measured over the *first 15 m,* to simulate real bobsled start, instead of only the first 5 m.

Another opportunity is to measure *more parameters* during the trials. For example, sensors for foot contact to check synchronization of the two running patterns are recommended. Measuring the speed during the entire race could have an added value as well. Moreover, *participants* could be *matched* based on physical appearances before testing. Participants could be tested on maximum force ability before matching. In our experiment, the participants were put randomly together in duos, what could lead to imbalanced combinations e.g. between big and strong subjects combined with a small and weak participant. In such duos, the bigger participant provided almost the full power, while the other participant could not press his maximum force and delivered most of the time underperforming results. These adjustments could result in an improved test setup.

Obtained results from test runs could be communicated to the athletes in a discussion afterwards or by visual, auditory or augmented haptic feedback. Subjects could be guided towards an optimized position or movement with innovative sensory communication aids [13]. Vibrotactile feedback could be a major tool to indicate quality of the performed run or steer position and movement of subjects, or to indicate synchronous patterns during training the start procedure. Further research should demonstrate which application of vibrotactile feedback is the most efficient for instructing bobsleigh athletes during the start procedure.

References

1. Dabnichki, P., Avital, E.: Influence of the postion of crew members on aerodynamics performance of two-man bobsleigh. J. Biomech. **39**, 2733–2742 (2006). https://doi.org/10.1016/j.jbiomech.2005.10.011
2. Braghin, F., Cheli, F., Donzelli, M., Melzi, S., Sabbioni, E.: Multi-body model of a bobsleigh: Comparison with experimental data. Multibody Syst. Dyn. **25**, 185–201 (2011). https://doi.org/10.1007/s11044-010-9218-7
3. Braghin, F., Donzelli, M., Melzi, S., Sabbioni, E.: A driver model of a two-man bobsleigh. Sport. Eng. **13**, 181–193 (2011). https://doi.org/10.1007/s12283-011-0066-3
4. Dabnichki, P.: Proceedings of the 10th International Symposium on Computer Science in Sports (ISCSS), vol. 392, pp. 193–194 (2016). https://doi.org/10.1007/978-3-319-24560-7
5. Brüggemann, G., Morlock, M., Zatsiorsky, V.M.: Analysis of the bobsled and men's luge events at the XVll olympic winter games in Lillehammer. J. Appl. Biomech. **13**, 98–108 (1997)
6. Lee, C.L., Huang, C.: XXIV ISBS Symposium 2006, Salzburg – Austria, vol. 1, pp. 2–5 (2006)
7. Kibele, A., Behm, D.: A laboratory test for the examination of alactic running performance. J. Sport. Sci. Med. **4**, 572–582 (2005)
8. Lopes, A.D., Alouche, S.R.: Two-man bobsled push start analysis. J. Hum. Kinet. **50**, 63–70 (2016). https://doi.org/10.1515/hukin-2015-0143
9. Baudouin, A., Hawkins, D.: Investigation of biomechanical factors affecting rowing performance. J. Biomech. **37**, 969–976 (2004). https://doi.org/10.1016/j.jbiomech.2003.11.011
10. Cuijpers, L.S., Passos, P.J.M., Murgia, A., Hoogerheide, A., Lemmink, K.A.P.M., de Poel, H.J.: Rocking the boat: does perfect rowing crew synchronization reduce detrimental boat movements? Scand. J. Med. Sci. Sport. **27**, 1697–1704 (2017). https://doi.org/10.1111/sms.12800
11. Lin, Y.T., Kuo, C.H., Chen, Y.C.: Differences in force gradation between tug-of-war athletes and non-athletes during rhythmic force tracking at high exertion levels. Chin. J. Physiol. **59**, 260–267 (2016). https://doi.org/10.4077/CJP.2016.BAE411
12. Lee, S., Kim, T., Lee, S., Kil, S., Hong, S.: Development of force measurement system of bobsled for practice of push-off phase. Proc. Inst. Mech. Eng. Part P J. Sport Eng. Technol. **229**, 192–198 (2015). https://doi.org/10.1177/1754337114565383
13. van Breda, E., Verwulgen, S., Saeys, W., Wuyts, K., Peeters, T., Truijen, S.: Vibrotactile feedback as a tool to improve motor learning and sports performance: a systematic review. BMJ Open Sport Exerc. Med. **3**, e000216 (2017). https://doi.org/10.1136/bmjsem-2016-000216

Risk Analysis in Mountain Bike, Using Questionnaire and Event Tree Analysis (ETA)

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Abstract. In this paper, we show the results related with the identification. the actions and conditions which have a negative repercussion on the practice of Downhill, by the application of questionnaire and Event Tree Analysis (ETA). The study includes 265 Amateur and Professional category athletes and observations in races and training zones like Brothers, “Valparaíso Cerro abajo”, “Valle el Retiro”, among others. **Results**: The elite category is more susceptible to having a greater number of serious injuries (45.8%) due to the speeds reached within the downhill slopes. The region most affected is the superior limbs (27,5%) due to the natural act of placing hands a number of 1 to 2 serious injuries. This is increased if they perform unsafe actions such as incorrect pedal selection, improper selection of footwear, of which conditions such as poor grip or material fatigue also influence. **Conclusion**. Focusing on the maintenance and correct conditions of the bicycle, the least performing this practice are Amateur, with 39,8% of the total population that does the sport without maintenance are exposed 55,5% to a number of 3 to 4 mild injuries. ETA give recommendation for each danger situation identified.

Keywords: Injury prevention and outdoor recreation · Mountain biking

1 Introduction

In particular, this sport has recently been the subject of increasing media attention due to several severe injuries among its athletes. However, little is known about the true risk of injury involved in participation. [1] Mountain bikes represent nowadays 50% of the world bicycle market and the discipline has gained a major significance as a recreational activity worldwide. [2] There are only a few studies about mountain biking. Recurrent disorders in the cervical and lumbar spine and the knee are the most common disorders in competitive mountain bikers. [3] Little epidemiological information exists on overuse injuries in elite road cyclists. Anecdotal reports indicate anterior knee pain and lower back pain may be common problems. [4] The vast majority of injuries sustained while cycling are considered minor in nature. [5, 6] Mountain biking has become an increasingly popular recreational and competitive sport with increasingly recognized risks. [7] Off-road cycling, commonly known as mountain biking, has increased in popularity, both in recreational and competitive forms [8].

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2 Method

This study used three types of collection data, described below:

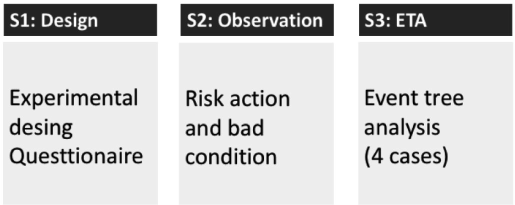

Fig. 1. Diagram of method

Questionnaire applied, using a survey of 265 riders from January until May 2017. (downhill mountain biking (DMB)). All athletes were recruited voluntarily via internet specifically by Google document. The survey has 26 questions related to: risky actions, field conditions and protection equipment in the competition.

Observations of meteorological factors, including precipitation and temperature. As well as, observation of risky actions in the competition DMB by athletes. This data were obtained from: “Skega” (Jan-2017); “Cerro del Jardin botanico” (Feb-2017), “Aq Brothers” (Feb-2017), “Valparaíso cerro abajo” (Feb-2017), “DH Tour National” (May-2017)

Event tree analysis (ETA), used to describe the logical connection between the potential successes and failures of defined safety systems or safety functions as they respond to the initiating event and the sequence of events (4 case studies).

3 Result

Two hundred and sixty five downhill athletes were recruited for this study to submit their general information as well as their specific injury questionnaires. Two hundred and six were Amateur category (78%) and 59 were Elite category. (22%). As shown in Fig. 1, from 1 to 5 years of experience (69%), from 6 to 10 (19%), from 11 to 15 (5%), from 16 to 20 (6%) and over 21 years of experience. (1%) (Fig. 2).

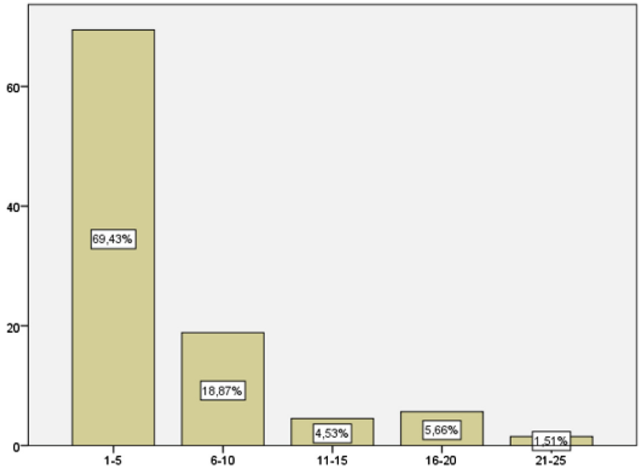

Fig. 2. This figure shows the distribution of years of experience.

3.1 Training Time

42.26% practice mountain biking at least 5 days a week, 20.75% do it 3 days a week, 17.36% 2 days a week, 10.19% 4 days a week and finally 9.43% do it 1 day a week.

3.2 Maximun Threshold of Effort

In the survey, 44.15% said that always reached the maximum effort at some point while practicing sports, 25.66% only Sometimes reached this Maximum Effort, a 22.64% regularly managed to reach that threshold followed by a 6.79% in which the respondents very few times reached the threshold and finally 0.75% affirmed that it had never reached that maximum threshold of effort.

3.3 Protective Equipment

Most common safety equipment used, included full face helmet (28%), full face helmet and safety glasses (17%), full face helmet, safety glasses and gloves (14%), full face helmet, gloves, safety glasses and protector jacket (25%) and finally full face helmet, safety glasses, gloves, protector jacket and shin guards (16%).

3.4 Status Recognition of the Walking Route

It is surprising to note that only 12% of athletes perform the recognition of the track prior to the competition in contrast to the 49% that never does.

3.5 Bicycle Maintenance

Regularly carries out maintenance on the bicycle (31%), rarely performs maintenance (31%), always performs this maintenance (24%), only performs it sometimes (13%) and finally never performs it. (1%)

3.6 Adverse Track Conditions

Of the total of 265 runners belonging to the Amateur and Elite categories, perform the sport if the conditions of the track are adverse (94%) versus those who do not practice the sport if there are bad conditions on the track. (6%)

3.7 Obstacles on the Track and Its Relationship with Accidents

The obstacles of the track have not influenced the accidents (33%), regularly the conditions of the track have influenced some type of injury during the practice of the sport (29%), very few times the obstacles of the track have influenced (17%), sometimes (14%) and always the obstacles on the track have caused the accident. (6%).

The most frequently affected body region was lower leg (43%), Superior limbs (40%), cervical spine (9%), head (5%) and without injury.

4 Correlations

Two types of correlations were used: Kruskal Wallis when there is more than one grouping variable and Mann-Whitman when there are only two, in the case of no correlation, its consequence is not ruled out, it can not be estimated on the basis to your results, a correct analysis. The statistical package of SPSS was used for the digestion of the data.

Applying Kruskal Wallis correlation, and working with an alpha significance level of 0.05, a level of significance of 0.279 > 0.05 obtained, therefore there is no difference between the number of minor or serious injuries and years of experience.

Using the Mann-Whitney test and working with a level of alpha significance of 0.05 correlating in this case the type of pedals with the slight consequences, we obtain a level of significance of 0.00 < 0.05, so in In this case there is a relationship between the type of pedals and the number of minor injuries.

Table 1. Relationship between the number of injuries and the type of pedals

	Tipos de Pedales		
	Fijaciones	Plataforma	Total
0 Lesiones	1,9%	1,5%	3,4%
1 a 2 Lesiones	15,8%	9,1%	24,9%
3 a 4 Lesiones	20,0%	51,7%	71,7%
	37,7%	62,3%	100,0%

Table 1 shows that according to the type of pedal, 51.7% of users of platform-type pedals are susceptible to having 3 to 4 or more mild injuries, versus 20% of users who use fixations, those who are equally susceptible to a number of 3 to 4 or more minor injuries.

Athletes who do not feed and hydrate correctly prior to practicing sports, makes them as susceptible to mild injuries as they do, there is no significant difference.

The Mann-Whitney test again and working with a level of alpha significance of 0.05 correlating in this case the realization of physical state, with the number of serious injuries, we obtain a level of significance of 0.083 > 0.05, so that in this case there is no correlation between the physical state and the number of serious injuries.

5 Event Tree Analysis

An Elite category runner, prior to a day of training in the descent race in an urban mountain bike, lowered his descent in the final sleeve, opting to obtain a podium due to his high performance. When he reached the stairs section, in which there was a marking or signaling of protruding parts, prior to a plane, the runner did not decrease speed in order to achieve descent of the second section of scales in the least time possible, without changing position of his body and impacting with his head part of a balcony of a building (Fig. 3).

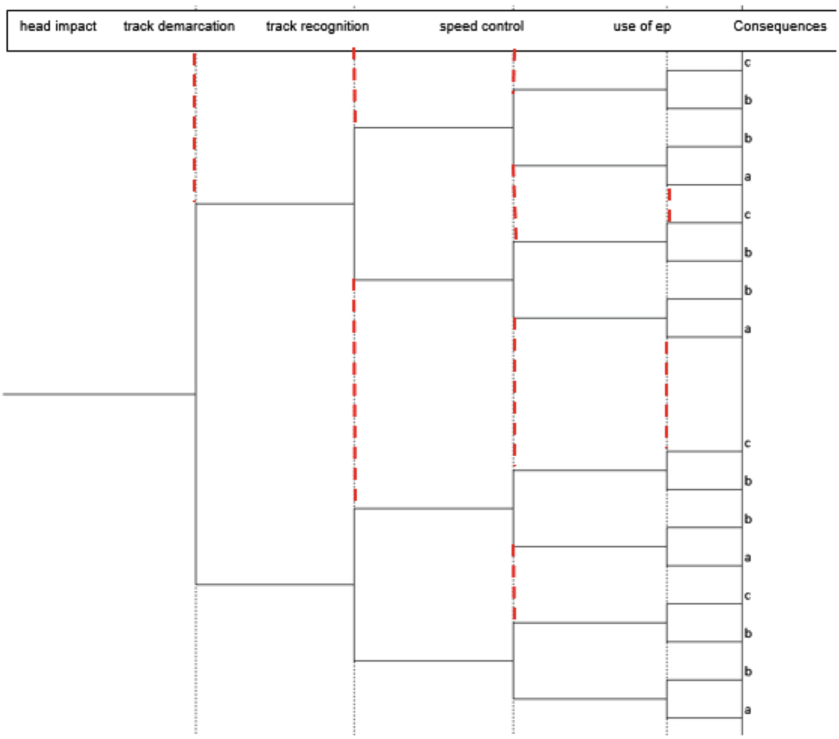

Fig. 3. This figure shows the events that together led to the consequences. (a,b,c) where a: dead; b: spine damage; c:multiple fractures.

6 Conclusion

In this study, a risk analysis was done to which mountain bikers are exposed, the state of the art reports among several authors that the practice of mountain biking is considered as an extreme high-risk sport.

Two nonparametric tests (Mann-Whitney and Kruskal Wallis) were used by using the SPSS 2016 statistical package. The results allowed us to conclude that the most damaged body region is the upper limb.

The risk analysis was used by the ETA for four cases: (a) slips on pedals falling off a bicycle; (b) violent blow in head due to unmarked court; (c) falls off track due to poor condition; (d) falls by gully for not making track walk.

Focusing on the maintenance and correct conditions of the bicycle, the least performing this practice are Amateur, with 39,8% of the total population that does the sport without maintenance are exposed 55,5% to a number of 3 to 4 mild injuries. ETA give recommendation for each dander situation identified.

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References

1. Becker, J., Schwirtz, A., Schumacher, Y., Hillebrecht, M.: A prospective study of downhill mountain biking injuries. Sport Med. **47**, 458–462 (2013)
2. Stapelfeldt, B.: Workload demands in mountain bike racing. Sport Med. **18**, 295 (2004)
3. Oehlert, K., Wolk, T., Hassenpflug, J.: Injuries, training and driving technique of competitive mountain-bikers. Sportverletz. Sportschaden **18**(4), 190–195 (2004)
4. Clarsen, B.: Overuse injuries in professional road cycles. Am. J. Sports Med. **38**(12), 2494–2501 (2010)
5. Pfeiffer, R.P.: Off-road biycle racing injuries. Clin. Sport Med. **13**, 207–218 (1994)
6. McGoldrick, N.: Acute traumatic spinal injury following bicycle accidents: a report of three cases Belgica. Acta Orthop. **78**, 409 (2012)
7. Kim, P.: Regional trauma system experience. J. Trauma Inj. Infect. Crit. Care (2006)
8. Taylor, N.: Epidemiology of injuries at the Australian 24 hour mountain bike championships. Official J. Paramedics Australas. **10** (2013)

The Influence of Dry Cupping of Differing Intensities on Heart Rate Variability

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Abstract. The aim of this study was to determine an appropriate range of negative pressure to ensure the treatment effect of cupping. Twenty healthy participants were enrolled to receive classic dry cupping treatments at three different pressure intensities (−100, −300, or −500 mmHg) for 10 min each. Heart rate variability (HRV) was measured before, during, and 10 min after cupping to assess changes in autonomic activity. Repeated measure ANOVA was used to analyze differences. Cupping at a pressure of −100 mmHg did not significantly change the HRV, but cupping at both −300 and −500 mmHg caused a significant improvement in HRV. The HRV responses did not differ significantly between cupping at −300 and at −500 mmHg, however. The significant increase in HRV occurred only during the recovery period after the cups were removed.

Keywords: Vacuum cupping · Negative pressure intensity
Autonomic nervous system

1 Introduction

Cupping is one of the oldest known medical therapies. The first descriptions of the practice in the West date back to the famous Egyptian Ebers Papyrus (1550 BC). It was also used in ancient Greek medicine. Cupping is used in Asian and Middle Eastern countries as well [1]. Although it is practiced in both Eastern and Western cultures, the theories for its effects and reasons for its application differ. Eastern medicine believes that cupping unblocks and corrects imbalances in the flow of Qi [2]. Greek physicians believed that cupping drew pathogenic factors to the surface, facilitating their elimination [3]. Although cupping has a long tradition, there is only limited evidence of its effectiveness. However, recent clinical studies have reported positive results of cupping in patients with musculoskeletal diseases. The procedure generates a vacuum, causing

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local edema, ecchymosis, or minor bleeding from the capillaries. Therefore, it is logical to assume that the effect of cupping is in some way similar to that of autohemotherapy [4]. Some researchers consider cupping to be a form of treatment in which somatic structures (e.g., skin, subcutaneous tissue, fascia) are favorably influenced by manipulation [5]. Arslan et al. (2014) found that cupping therapy restored sympathovagal imbalance by stimulating the peripheral autonomic nervous system, which might make it useful for preventing cardiac arrhythmias [6]. Nevertheless, a psychosomatic theory advocated by several investigators suggests that the therapeutic effect of cupping is purely a placebo effect [7, 8]. Numerous clinical trials and several systematic reviews have recently appeared, but their conclusions are unfortunately far from uniform.

Many previous studies have not explicitly quantified the precise cupping dose used (i.e., pressure, time, and location). Most reports have been experience-based with only rough estimates, particularly in trying to quantify the negative pressure intensity. These non-quantitative experimental designs have likely contributed to the inconsistent results of research on cupping efficacy. We designed this study to carefully quantify the negative cupping pressure with a mechanical pump, examining the effects of different cupping intensities on the activity of the autonomic nervous system (ANS). Heart rate variability (HRV) is a non-invasive research tool in cardiology. It is a relevant marker reflecting modulation of cardiac function by the sympathetic and parasympathetic components of the ANS. In general, a low HRV has been found to be a significant predictor of cardiac mortality and morbidity, indicating that a high HRV is more desirable [9]. The clinical application of HRV is mainly for assessment of cardiovascular and metabolic illness. As cupping has been shown to decrease the rate of ischemia-induced arrhythmias [10], it can be speculated that cupping may increase HRV. However, it remains unclear whether different levels of cupping intensity have different effects on HRV. Therefore, the current study investigated the effect of cupping on HRV in healthy volunteers during and after the procedure when performed at different vacuum intensities. However, we hypothesized that it would help to define a more appropriate range of negative cupping pressures to ensure an adequate treatment effect.

2 Methods

2.1 Participants

A total of 20 healthy college students (14 men and 6 women) participated in the study. The mean age was 22.2 ± 1.3 years, height 166.3 ± 2.0 cm, weight 64.1 ± 3.3 kg, and body mass index 22.9 ± 0.8 kg/m^2. Exclusion criteria included current use of anticoagulants, coagulopathy, or having undergone any form of cupping therapy in the previous 12 months. The participants were fully informed about the study protocol and gave informed written consent to participate in the experimental procedure. All applicable institutional and governmental regulations concerning the ethical use of human volunteers were followed during the course of this research.

2.2 Quantitative Pressure of the Dry Cupping Procedure

To quantify cupping intensity at different levels of negative pressure, we used electromechanical pumps with pressure gauges (DF-750 Portable Suction, Doctor's Friend Medical Instrument Co., Taiwan) to create precise negative pressures (Fig. 1).

Fig. 1. Electromechanical suction pump and acrylic cups for cupping.

Each cupping procedure was performed as follows. The participants were seated and leaning forward with their arms on a table for support. Acrylic cups with a 6.5-cm outer diameter and a 5.5-cm inner diameter were used (Shen-Nong Cupping R0416179, Income Instrument Co., Ltd., Taiwan). Five points on the upper trapezius and latissimus dorsi muscles bilaterally were selected. These are classic cupping points chosen for all such treatments (Fig. 2). Arslan et al. (2014) performed wet cupping on the same areas of the back and found significant improvement in autonomic activity [6].

We applied cupping intensities in the range of −400 to −700 hPa (equivalent to −300 to −525 mmHg) that have been used in previous studies [11, 12]. We designated three levels: (1) low pressure, −100 mmHg; (2) medium pressure, −300 mmHg; and (3) high pressure, −500 mmHg. The cups were placed in the same position throughout the experiments (Fig. 2), with each level of negative pressure applied as described below for 10 min at a time.

Fig. 2. Vacuum application during dry cupping.

2.3 Design

We divided the experiment into two trials randomly scheduled one week apart. The heart rate was observed at baseline for 5 min, then a pressure of −100 mmHg was applied for 10 min. After the cup was removed, 10 min were allowed for recovery, immediately followed by cupping at a higher intensity for 10 min, with another 10 min for recovery after that. The first trial assessed the effects of −100 versus −300 mmHg and the second trial compared −100 versus −500 mmHg, each trial lasting about 45 min (Fig. 3). The HRV was evaluated before, during, and 10 min after cupping. The first half of each trial was designed to examine whether low-pressure (−100 mmHg) cupping had an impact on HRV, while the second half was intended to look for differences in the HRV response to cupping at higher intensities.

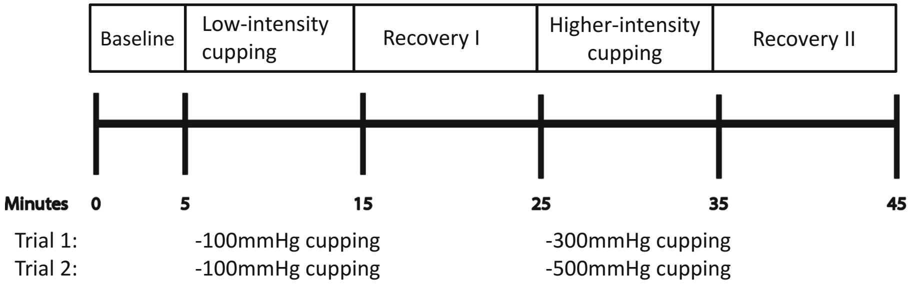

Fig. 3. Study design for cupping

2.4 Measurement of HRV

HRV is measured by variation in R–R intervals. Electrophysiological signals were recorded for each participant using a miniature physiological signal recorder (TD1; Taiwan Telemedicine Device Company, Kaohsiung, Taiwan). For each cupping intensity (i.e., low, medium, or high), the HRV was measured for 5 min during three separate periods: (1) before cupping, (2) the final 5 min of the 10-minute cupping procedure, and (3) the final 5 min of the 10-min recovery period. Electrocardiographic leads were used to record participants' R–R intervals. The signals were recorded in real time after analog-to-digital conversion (8-bit) at a sampling rate of 500 Hz. The R–R intervals in milliseconds were calculated from beat to beat with a customized software program developed by Dr. Kuo [13]. Frequency domain analysis was performed by nonparametric fast Fourier transform. The power spectrum was then quantified into frequency domain measurements. Total power (0–0.4 Hz), low-frequency (LF, 0.04–0.15 Hz), and high-frequency (HF, 0.15–0.4 Hz) power components were converted into absolute values of power, and any skewness in the distribution of the parameters was corrected by transforming them all logarithmically. Total power is a marker of autonomic nervous activity, HF power reflects parasympathetic nervous activity, and LF power reflects partial contributions from both sympathetic and parasympathetic nervous activity. To detect a sympathetic effect on HRV, total power was used to normalize LF or HF power expressed as a percentage (LF% or HF%). The ratio of low to high frequencies (LF/HF) was also calculated and used as an index of sympathovagal balance [14]. For more detailed HRV analysis methods and procedures, please refer to our previously published reports [15, 16].

2.5 Statistical Analysis

Data are presented as the mean and standard error of the mean (mean ± SEM). A two-way (trial × time) repeated-measures analysis of variance (RM-ANOVA) was used to analyze the differences within and between the trials and the trial-by-time interaction. The analysis of HRV response was divided into two parts, first to low-pressure cupping and second to higher-pressure cupping. The former compared HRV response at baseline, during low-intensity cupping, and during recovery I. The latter compared values from recovery I, during higher-intensity cupping, and during recovery II (Fig. 3). Bonferroni corrections were used for a post-hoc comparison of the two higher-intensity cupping procedures to determine whether the main effect on HRV occurred when the cups were on the skin or after they were removed. Statistical analyses were conducted using PASW Statistics 23.0 (SPSS Inc., Chicago, IL, USA) software. The significance was set at $p < 0.05$.

3 Results and Discussion

3.1 Effect on HRV of Dry Cupping at a Negative Pressure of 100 mmHg

HRV before, during, and 10 min after cupping at −100 mmHg were compared between the two trials. The RM-ANOVA comparison of the values of total power, LF, HF, LF/HF, LF%, and HF% collected during the two trials indicated that the values did not differ significantly between the first and second trials ($p > 0.10$). No significant difference was observed among the three time periods HRV was assessed ($p > 0.10$). In addition, there was no significant difference in trial-by-time interaction ($p > 0.05$). The above results indicate that cupping at a negative pressure of 100 mmHg did not significantly change HRV (Table 1). In most cases, there was no marked ecchymosis at the cupping sites after the cups were removed.

Table 1. Effects of −100 mmHg cupping on parameters of heart rate variability (n = 20)

Parameters	Trials	Before cupping	During cupping	10 min recovery	P value (trial)	P value (time)	P value (Trial * time)
TP [ln(ms^2)]	1st	7.31 ± 0.11	7.45 ± 0.14	7.48 ± 0.13	0.417	0.359	0.175
	2nd	7.35 ± 0.14	7.38 ± 0.16	7.32 ± 0.16			
LF [ln(ms^2)]	1st	6.65 ± 0.13	6.79 ± 0.15	6.86 ± 0.15	0.500	0.193	0.443
	2nd	6.66 ± 0.16	6.74 ± 0.15	6.70 ± 0.18			
HF [ln(ms^2)]	1st	5.59 ± 0.14	5.75 ± 0.17	5.84 ± 0.18	0.492	0.249	0.084
	2nd	5.67 ± 0.19	5.65 ± 0.21	5.65 ± 0.21			
LF/HF (ln ratio)	1st	1.05 ± 0.09	1.04 ± 0.08	1.02 ± 0.11	0.923	0.789	0.759
	2nd	0.99 ± 0.13	1.09 ± 0.12	1.04 ± 0.13			
LF (%)	1st	71.0 ± 1.8	71.2 ± 1.6	70.0 ± 1.9	0.922	0.536	0.762
	2nd	69.8 ± 2.6	72.2 ± 2.4	70.8 ± 2.5			
HF (%)	1st	20.5 ± 1.3	20.6 ± 1.2	23.1 ± 1.8	0.691	0.230	0.579
	2nd	22.5 ± 2.2	21.1 ± 2.3	22.4 ± 1.9			

TP, LF, HF, LF/HF, LF%, and HF% are all parameters of the heart rate variability.
TP: total power is the marker of autonomic nervous activity,
LF: low frequency power reflects both sympathetic and parasympathetic modulations,
HF: high frequency reflects parasympathetic activity,
LF/HF (In ratio): the ratio of LF to HF reflects sympathovagal balance,
LF%: LF in normalized unit reflects sympathetic activity,
HF%: HF in normalized unit reflects sympathetic inhibition.

3.2 Effect on HRV of Cupping with Medium and High Intensity Negative Pressure

We analyzed the effect of higher negative pressures on HRV, comparing the responses to cupping at −300 and −500 mmHg vacuum pressure. All HRV variables except for HF% differed significantly before and after cupping ($p < 0.05$) (Table 2), indicating that autonomic activity was significantly higher after than before cupping. However, none of the HRV measures differed significantly between trials or in time-and-trial interaction ($p > 0.10$). Cupping at −500 mmHg caused more obvious ecchymosis than did a pressure of −300 mmHg, but the HRV results did not differ between the two higher pressures. Cupping at either higher intensity was sufficient to affect HRV, with the main effect being an increase in the total power of the autonomic activity (TP and LF, $p = 0.001$), including increases in both sympathetic (LF%, $p = 0.003$) and parasympathetic (HF, $p = 0.050$) activity.

Table 2. Effects of different intensity cupping on parameters of heart rate variability (n = 20)

Parameters	Trials	Before cupping	During cupping	10 min recovery	P value (trial)	P value (time)	P value (Trial * time)
TP [ln(ms^2)]	−300 mmHg	7.48 ± 0.13	7.44 ± 0.13	7.69 ± 0.15	0.159	0.001	0.727
	−500 mmHg	7.32 ± 0.16	7.35 ± 0.13	7.54 ± 0.15			
LF [ln(ms^2)]	−300 mmHg	6.86 ± 0.15	6.74 ± 0.15	7.08 ± 0.17	0.197	0.001	0.977
	−500 mmHg	6.70 ± 0.18	6.60 ± 0.14	6.94 ± 0.16			
HF [ln(ms^2)]	−300 mmHg	5.84 ± 0.18	5.89 ± 0.17	6.03 ± 0.18	0.118	0.050	0.944
	−500 mmHg	5.65 ± 0.21	5.68 ± 0.19	5.80 ± 0.19			
LF/HF (ln ratio)	−300 mmHg	1.02 ± 0.11	0.85 ± 0.13	1.04 ± 0.12	0.542	0.025	0.848
	−500 mmHg	1.04 ± 0.13	0.92 ± 0.13	1.14 ± 0.10			
LF (%)	−300 mmHg	70.0 ± 1.9	67.4 ± 2.8	72.3 ± 2.5	0.595	0.003	0.922
	−500 mmHg	70.8 ± 2.5	68.3 ± 2.5	74.0 ± 1.9			
HF (%)	−300 mmHg	23.1 ± 1.8	24.9 ± 2.2	22.4 ± 2.0	0.380	0.150	0.774
	−500 mmHg	22.4 ± 1.9	22.9 ± 2.1	20.4 ± 1.4			

TP, LF, HF, LF/HF, LF%, and HF% are all parameters of the heart rate variability.

3.3 Cupping Improved HRV over Time

In order to clarify whether cupping improved HRV primarily during cup attachment or after the cups were removed, we used *post-hoc* analysis to compare the HRV activity before, during cupping, and in the 10-min recovery after the procedure. Our findings indicated a significant increase in HRV only from the cupping procedure to the recovery period, especially in TP, LF, LF/HF, and LF% (T2 > T1, Table 3). There was no significant difference in the HRV between the periods before and during cupping (T0 vs. T1, Table 3). This result seems to indicate that the effect of increasing HRV occurred mainly after the cupping pressure was released. The 10-min cupping period itself did not demonstrate significant improvement in HRV over the value before the cups were applied.

Table 3. Immediate and short-term effects of cupping on heart rate variability (n = 20)

Parameters	Before cupping (T0)	During cupping (T1)	10 min recovery (T2)	P value	Bonferroni test
TP [$\ln(ms^2)$]	7.40 ± 0.14	7.40 ± 0.12	7.62 ± 0.14	0.001	T2 > T1; T2 > T0
LF [$\ln(ms^2)$]	6.78 ± 0.15	6.67 ± 0.13	7.01 ± 0.15	0.001	T2 > T1
HF [$\ln(ms^2)$]	5.75 ± 0.18	5.78 ± 0.17	5.92 ± 0.17	0.050	
LF/HF (ln ratio)	1.03 ± 0.10	0.89 ± 0.12	1.09 ± 0.09	0.025	T2 > T1
LF (%)	70.4 ± 1.8	67.9 ± 2.3	73.1 ± 1.8	0.003	T2 > T1
HF (%)	22.7 ± 1.5	23.9 ± 1.9	21.4 ± 1.4	0.150	

TP, LF, HF, LF/HF, LF%, and HF% are all parameters of the heart rate variability.

4 Conclusions

To improve the activity of the ANS requires sufficient cupping pressure. An adequate stimulus intensity can increase autonomic activity after the cup is removed. However, there was no significant difference in HRV between pressures of −300 and −500 mmHg. It is recommended that cupping be performed without excessive pressure to avoid unnecessary stress to the skin. We found that the cupping effect on HRV was not evident within the 10 min of cupping itself but only during the recovery period after the cups were removed. Appropriate cupping therapy should enhance overall ANS activity, including improvement in both sympathetic and parasympathetic activity.

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References

1. Rozenfeld, E., Kalichman, L.: New is the well-forgotten old: the use of dry cupping in musculoskeletal medicine. J. Bodywork Mov. Ther. **20**(1), 173–178 (2016)
2. Chirali, I.Z.: Traditional Chinese Medicine Cupping Therapy. Elsevier Health Sciences, London (2014)
3. Kose, A.A., Karabağli, Y., Cetin, C.: An unusual cause of burns due to cupping: complication of a folk medicine remedy. Burns **32**(1), 126–127 (2006)
4. Klemparskaya, N., et al.: Immunomodulating effect of autohaemotherapy (a literature review). J. Hyg. Epidemiol. Microbiol. Immunol. **30**(3), 331–336 (1985)
5. Musial, F., Spohn, D., Rolke, R.: Naturopathic reflex therapies for the treatment of chronic back and neck pain-part 1: neurobiological foundations. Complement. Med. Res. **20**(3), 219–224 (2013)
6. Arslan, M., et al.: Wet cupping therapy restores sympathovagal imbalances in cardiac rhythm. J. Altern. Complement. Med. **20**(4), 318–321 (2014)
7. Yoo, S.S., Tausk, F.: Cupping: east meets west. Int. J. Dermatol. **43**(9), 664–665 (2004)

8. Kouskoukis, C.E., Leider, M.: Cupping: the art and the value. Am. J. Dermatopathol. **5**(3), 235–240 (1983)
9. Stein, P., Kleiger, R.: Insights from the study of heart rate variability. Ann. Rev. Med. **50**, 249 (1999)
10. Shekarforoush, S., et al.: Cardiac effects of cupping: myocardial infarction, arrhythmias, heart rate and mean arterial blood pressure in the rat heart. Chin. J. Physiol. **55**(4), 253–258 (2012)
11. Zhao, X., et al.: Effect of time and pressure factors on the cupping mark color. Zhongguo Zhen Jiu = Chin. Acupunct. Moxibustion **29**(5), 385–388 (2009)
12. El Sayed, S.M., et al.: Percutaneous excretion of iron and ferritin (through Al-hijamah) as a novel treatment for iron overload in beta-thalassemia major, hemochromatosis and sideroblastic anemia. Med. Hypotheses **83**(2), 238–246 (2014)
13. Kuo, T.B., et al.: Effect of aging on gender differences in neural control of heart rate. Am. J. Physiol. Heart Circ. Physiol. **277**(6), H2233–H2239 (1999)
14. Chen, C.L., et al.: Immediate effects of smoking on cardiorespiratory responses during dynamic exercise: arm vs. leg ergometry. Front. Physiol. **6**, 376 (2015)
15. Chen, C.L., et al.: The effects of cupping therapy on reducing fatigue of upper extremity muscles—a pilot study. In: International Conference on Applied Human Factors and Ergonomics. Springer (2017)
16. Task Force of the European Society of Cardiology: Heart rate variability standards of measurement, physiological interpretation, and clinical use. Eur. Heart J. **17**, 354–381 (1996)

Three-Dimensional Elastography Gradient of the Plantar Soft Tissue: Methodology and Preliminary Study

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Abstract. Diabetic foot ulcers are a significant complication in people with diabetes mellitus. The changes of mechanical properties of plantar tissues associated with diabetes may contribute to a high incidence of diabetic foot ulcers. This study investigated the feasibility of using three-dimensional (3D) elastography to measure 3D elasticity of the fat pad and then calculate 3D elasticity gradients of the foot. This method may improve the detection of people at risk for diabetic foot ulcer. Elastography with a soft ratio measurement may provide a visualization of plantar soft tissues for clinicians to diagnose foot ulcer risk. In this study, we measured B-mode and elastic ultrasound images at the first metatarsal head in five volunteers. The soft tissue contains four layers, including inner layer (Q1, near bone surface), sub-inner layer (Q2), sub-outer layer (Q3), and outer layer (Q4, near skin surface). The elasticity values were significantly greater in the Q3 layer compared to the Q1 layer. The elasticity gradient values were significantly smaller in the Q3 layer compared to the Q2 layer. The correlation between the elasticity and elasticity gradient was $r = -0.88$ in the Q3 layer.

Keywords: Elastography gradient · Elasticity maps · Stiffness
Diabetic foot ulcer

1 Introduction

One of the most serious complications of diabetes mellitus is diabetic foot ulcers [1]. Diabetic peripheral neuropathy causes loss of protective sensation. In addition, it causes

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the changes of compressive mechanical properties of plantar soft tissue. These changes contribute to the development of diabetic foot ulcers.

Diabetes causes a decrease in elasticity of plantar tissue. Hsu and co-workers [2] showed that the collagen fibrils in diabetic samples were ruptured with unclear striation and uneven distribution. This may partly explain the poor rebound phenomenon resulting in the high impact energy in diabetic heel pads. These changes could limit tissues' ability to withstand repetitive plantar pressures during walking, thus increasing risks for foot ulcers [3, 4]. We previously demonstrated that diabetics had a higher effective Young's modulus and initial modulus of quasi-linear viscoelastic module compared to non-diabetics [4]. These findings provide some evidences to correlate atrophy of the fat pad to increased ulcer incidence. Plantar foot, including the heel fat pad area, also has lower perfusion due to microangiopathy which is connected with the increased glycation products [5]. Histomorphometric analysis revealed that an average of 30% smaller in the mean cell area and 16% smaller in the mean cell diameter in the atrophic pads compared to the normal heel fat pads [6]. However, some studies showed that systemic atrophy of sub-metatarsal head (sub-MTH) fat pads is not present in the diabetic foot and may not explain the structural changes previously proposed by noninvasive imaging [4, 7–9].

Real time ultrasound elastography can be used to measure the soft tissue elasticity of the fat pad of the diabetic foot [9, 10]. Furthermore, these imaging data can be used to develop various computational models of diabetic foot for the assessment of stress distributions in plantar soft tissues [11, 12]. The three-dimensional (3D) elastography computational models may provide additional information to quantify the elasticity patterns of the cross sectional layer of the diabetic foot. The purpose of this study was to develop computational models of the foot using 3D elastography. We hypothesized that elasticity would be different in each layer of plantar pad in diabetics compared to non-diabetics.

2 Methods

2.1 Participants

We intended to develop 3D elastography computational models in non-diabetics before recruiting diabetics. Five volunteers were recruited, including 3 females and 2 males. Subjects with diabetes, gross foot deformities (except minor toe clawing) and prior foot amputations/major surgeries were excluded for a more homogeneous population. The demographic data of the subjects were: age 27.5 ± 9.2 years, weight 71.0 ± 23.8 kg, height 1.71 ± 0.15 m, body mass index (BMI) 24.1 ± 5.4 kg/m^2. The research protocol was explained to the volunteers who signed an informed consent form.

2.2 Elasticity Measurements

Plantar soft tissue was measured by an elastographic ultrasound. Aloka Pro Sound Alpha 7 ultrasound machine (Hitachi Medical, Tokyo, Japan) with linear array transducer (UST-5412; frequency range, 5–13 MHz, Aloka, Tokyo, Japan) was used to measure both color Doppler and real-time tissue elastography of the plantar soft tissues at the first sub-MTH, the most common site for diabetic foot ulcers [13, 14]. Ultrasound images included B-mode ultrasound and elastographic ultrasound images. The strain ratio was calculated by using strain elastography function.

The ultrasound protocols were based on the methods described in the literature [15, 16], and are summarized here. The area of interest was scanned in the transverse planes of the subcutaneous soft tissue of first metatarsal head. A slight rhythmic compression decompression movement was applied consistently in order to minimize iatrogenic artifacts. We monitored the strain indicator on the screen during imaging and maintained the compression levels between 3 and 4. The indicator of strain ratio is a numeric scale ranging from 0 to 100 that indicates the compression amount applied to the tissue. Five images of elastography of the subcutaneous soft tissue were used to extract the value of strain ratio parameters.

2.3 Data Analysis and Statistics

Elasticity and elasticity gradient were calculated from the image data of elastography. These steps included: (1) region of first sub-MTH fat pad; (2) RGB to bit value and quartile layer; (3) composed four layer into 9 × 9 × 4 model; (4) obtain the elasticity and elasticity gradient by 9 × 9 × 4 model; (5) obtain the reasonable value by window filter. Then, the elasticity and elasticity gradients at the same coordinate were obtain from the four elasticity layers and elasticity gradient layers (Fig. 1).

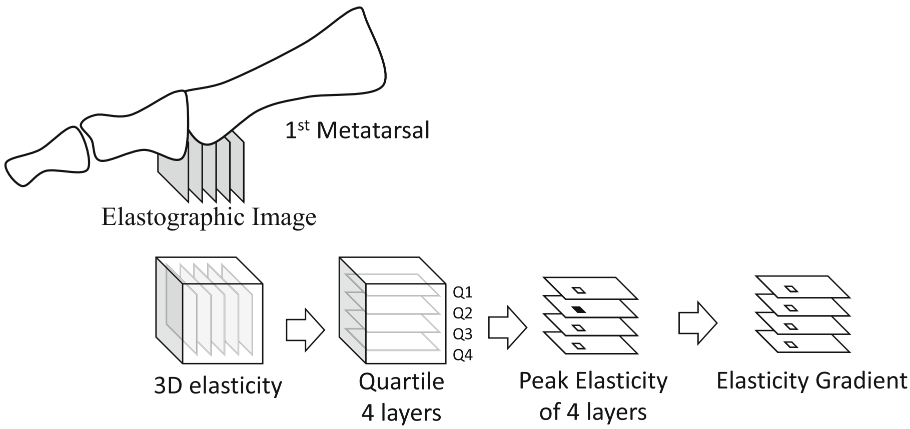

Fig. 1. Elasticity images of subcutaneous soft tissue layer of the foot. The plantar tissue consists of four layers, including the inner layer (Q1, near bone surface), sub-inner layer (Q2), sub-outer layer (Q3), and outer layer (Q4, near skin surface).

(1) **Region of First Sub-MTH Fat Pad**

In the right image, color mapping (blue to green, hard; yellow, medium; and red, soft) of the tissue strain was superimposed on the B-mode image. A square frame indicates the region of interest for the Metatarsal head pad without the bone (Fig. 2).

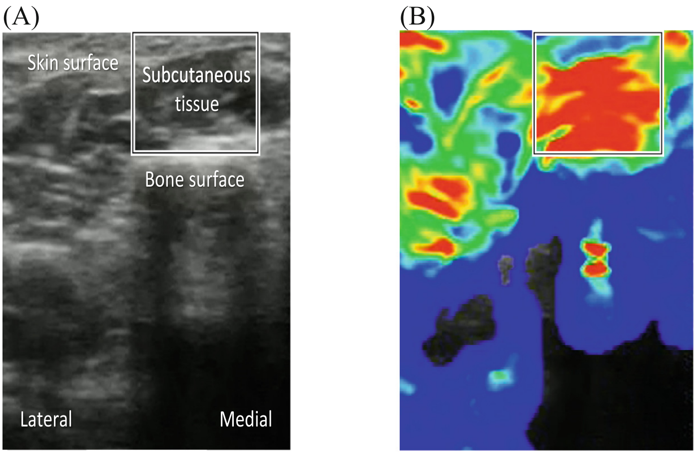

Fig. 2. B-mode (left) and elastographic (right) images of the 1st metatarsal head pad. The region is 100 × 100 pixels. Images from a female volunteer.

(2) RGB to Bit Value and Quartile Layer

The numeric scale ranging of elasticity is from 0 to 100 strain ratio, we converted RGB modes to 6-bit values (64 different levels) and quartile layer. Elastographic images were divided into four sections. Soft tissue contains four layers, including the inner layer (Q1, near bone surface), sub-inner layer (Q2), sub-outer layer (Q3), and outer layer (Q4, near skin surface) (Fig. 3).

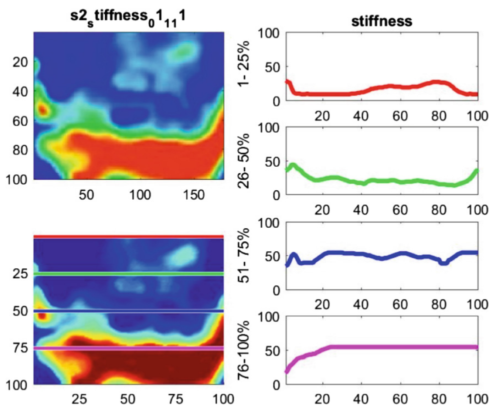

Fig. 3. Elastographic (left) images divided into four sections for four soft tissue layers. Maximal values were got from vertical node of each section. Four stiffness ratio line were got from each maximal values.

(3) Four Layer into 9 × 9 × 4 Model

Resize the 5 × 100 × 4 model into the 9 × 9 × 4 model (Fig. 4).

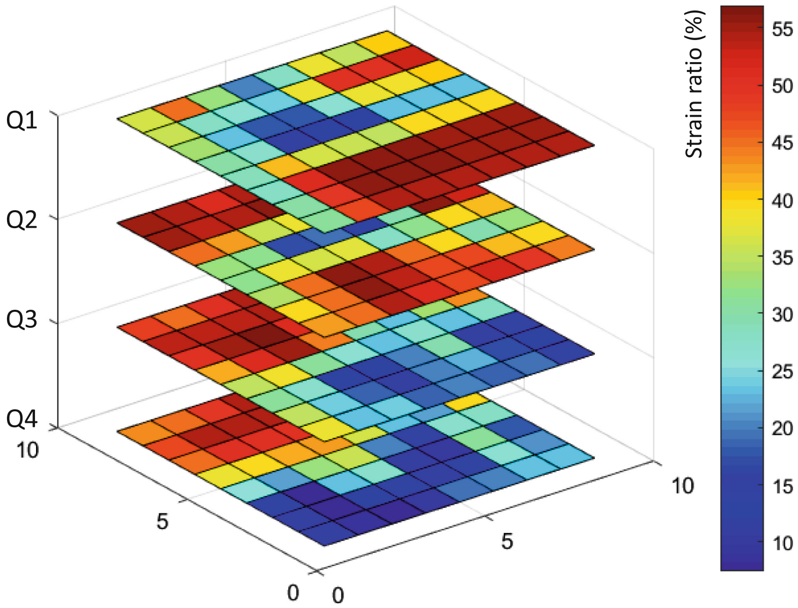

Fig. 4. Four layers of 9 × 9 × 4 model in the soft tissue of sub-MTH fat pad. Tissue layer contains inner layer (Q1, near bone surface), sub-inner layer (Q2), sub-outer layer (Q3), and outer layer (Q4, near skin surface).

(4) Elasticity and Elasticity Gradient by 9 × 9 × 4 Model

The gradient represents the slope of the tangent of the graph of the function. Additionally, the gradient points in the direction of the greatest rate of increase of the function, and its magnitude is the slope of the graph in that direction (Fig. 5).

[*FX*, *FY*] = gradient (*F*) returns the *x* and *y* components of the two-dimensional numerical gradient of matrix *F*. The output *Fx* and *Fy* correspond to $\partial F/\partial x$ and $\partial F/\partial y$, which are the differences in the *x* (horizontal) direction and *y* (vertical) direction, respectively. The spacing between points in each direction is assumed to be 1.

$$\nabla F = (\partial F/\partial x)i + (\partial F/\partial y)j \tag{1}$$

Where *i* and *j* are the standard unit vectors in the directions of the *x* and *y* coordinates, respectively.

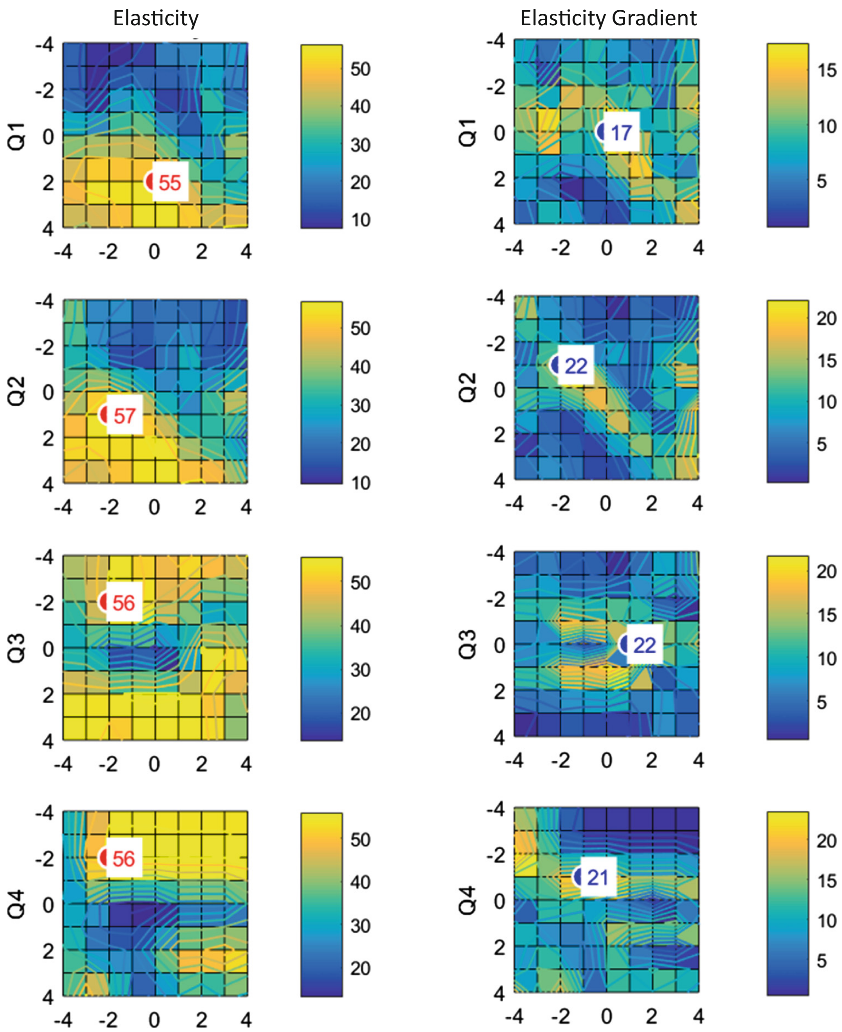

Fig. 5. The elasticity and elasticity gradient of four soft tissue layers.

(5) **Window Filter**

The peak elasticity of four layers match a location of coordinate. According the same location of coordinate, we found another 3 elasticity values in other 3 layers. We also found 4 elasticity gradient values in 4 layers at the same a location of coordinate. In the literature, window filters are also known as convolution filters as they can be represented using a matrix multiplication. The value average within a widow of the node is an index has been reported to strike a reasonable balance during matrix results [17, 18]. The 2D Average filtering example is using a 3 × 3 sampling window. Keeping border values is unchanged. Consider the following 3 by 3 average filter:

$$\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix} \tag{2}$$

We can write it mathematically as:

$$I\_new\,(x, y) = \sum\nolimits_{i=-1}^{1} \sum\nolimits_{j=-1}^{1} IxI\_old\,(x + I, y + j) \tag{3}$$

After the peak elasticity index window filters, we obtained the reasonable elasticity in four layers.

We analyzed the intra-observer variability by intra-class correlation coefficient (ICC). The distribution of values by variable using a one-sample Kolmogorov-Smirnov test. The differences in the elasticity and elasticity gradient among Q1 to Q4 were examined using an independent t test. The values were presented as the mean ± standard deviation. Correlations between the elasticity and elasticity gradient in each layer, Q1 to Q4, were determined using a Pearson product-moment correlation analysis. The level of the significance was set at 0.05.

3 Results and Discussion

Repeated measurements of the strain ratios showed high enough intra-class correlation agreement (ICC value = 0.81 (CI 0.57–0.95), $P < 0.05$). The results presented all of the parameters were normal distribution. The elasticity values was significantly greater in Q3 layer (44.9 ± 5.0 strain ratio) compared to Q1 layer (27.8 ± 12.1, $P < 0.05$, Fig. 6a). The elasticity gradient values was significantly smaller in Q3 layer (7.1 ± 1.5 strain ratio gradient) compared to Q2 layer (10.8 ± 3.4 strain ratio gradient, $P < 0.05$, Fig. 6b). The correlation between the elasticity and elasticity gradient was r = −0.88 in Q3 layer ($P < 0.05$, Fig. 7).

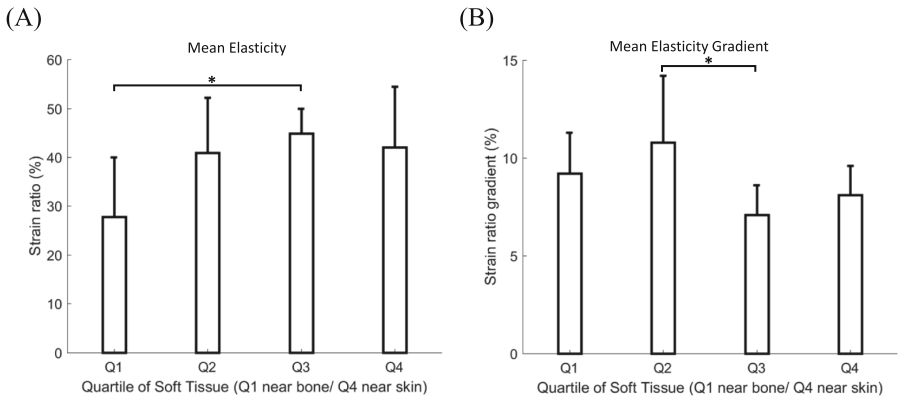

Fig. 6. The comparison of elasticity and elasticity gradient among Q1 to Q4; * indicates $P < .05$.

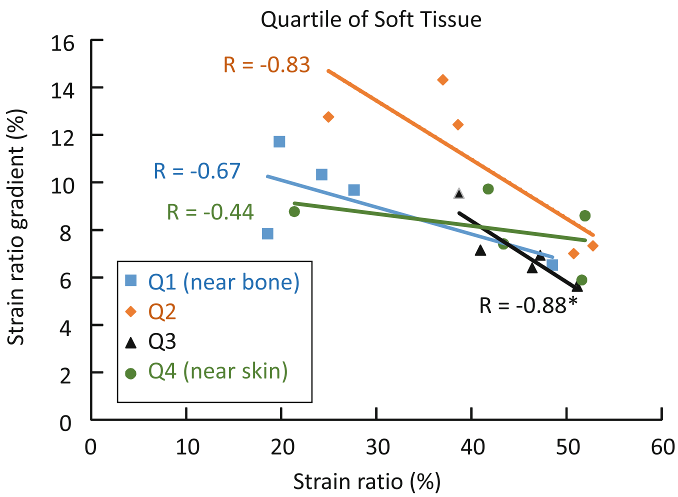

Fig. 7. The relationship between elasticity and elasticity gradient. The scatter plots to show Q1 (square), Q2 (diamond), Q3 (triangle), and Q4 (circle). * indicates $P < .05$.

In our previously study, compared to non-diabetics, the initial modulus of quasi-linear viscoelastic (QLV) model increased nearly eight times in the diabetics, the initial modulus may play a more influential role on foot ulceration in diabetics [4]. In this study, our data suggest that Q3 (sub-outer layer) had greater elasticity and smaller elasticity gradient. There's an interesting relationship between Q3 and initial modulus in diabetic foot.

The elasticity gradient values was significantly smaller in Q2 (sub inner layer). It is recommended that further research needs to test and evaluate potential diabetic foot ulcers in sub inner layer.

Derived from our previously published paper [19], the positive correlation between plantar pressure and plantar pressure gradient was considerably higher in the diabetics. In this study, we further demonstrate that a significant negative correlation between the elasticity and elasticity gradient in Q3 (sub-outer layer). These results may help clinicians to know the relationship between elasticity and elasticity gradient in diabetics.

We demonstrated that not only the diabetics had a significantly greater effective Young's modulus, but also had greater initial modulus of quasi-linear viscoelasticity compared to non-diabetics in our previous study [4]. That implies that the compressive mechanical properties of Q3 (sub-outer layer) soft tissue near the skin surface may have smaller elasticity in fat pad of the first metatarsal head of the diabetic foot.

The 3D elasticity corresponding to 3D elasticity gradient may allow a precise detection of the risk for diabetic foot ulcer. Our results suggest that 3D elasticity corresponding to 3D elasticity gradient offers potential to investigate the mechanical properties of soft tissues in vivo non-invasively.

References

1. Burns, S., Jan, Y.K.: Diabetic foot ulceration and amputation. In: Kim, C.T. (ed.) Rehabilitation Medicine, pp. 1–20. InTech Publisher, Croatia (2012)
2. Hsu, T.C., Lee, Y.S., Shau, Y.W.: Biomechanics of the heel pad for type 2 diabetic patients. Clin. Biomech. **17**, 291–296 (2002)
3. Chatzistergos, P.E., Naemi, R., Sundar, L., Ramachandran, A., Chockalingam, N.: The relationship between the mechanical properties of heel-pad and common clinical measures associated with foot ulcers in patients with diabetes. J. Diabetes Complications **28**, 488–493 (2014)
4. Jan, Y.K., Lung, C.W., Cuaderes, E., Rong, D., Boyce, K.: Effect of viscoelastic properties of plantar soft tissues on plantar pressures at the first metatarsal head in diabetics with peripheral neuropathy. Physiol. Meas. **34**, 53–66 (2013)
5. Jan, Y.K., Shen, S., Foreman, R.D., Ennis, W.J.: Skin blood flow response to locally applied mechanical and thermal stresses in the diabetic foot. Microvascular research (2013)
6. Buschmann, W.R., Jahss, M.H., Kummer, F., Desai, P., Gee, R.O., Ricci, J.L.: Histology and histomorphometric analysis of the normal and atrophic heel fat pad. Foot Ankle Int. **16**, 254–258 (1995)
7. Waldecker, U., Lehr, H.-A.: Is there histomorphological evidence of plantar metatarsal fat pad atrophy in patients with diabetes? J. Foot Ankle Surg. **48**, 648–652 (2009)
8. Bus, S.A., Maas, M., Cavanagh, P.R., Michels, R.P.J., Levi, M.: Plantar fat-pad displacement in neuropathic diabetic patients with toe deformity. Diabetes Care **27**, 2376–2381 (2004)
9. Naemi, R., Chatzistergos, P., Suresh, S., Sundar, L., Chockalingam, N., Ramachandran, A.: Can plantar soft tissue mechanics enhance prognosis of diabetic foot ulcer? Diabetes Res. Clin. Pract. **126**, 182–191 (2017)
10. Naemi, R., Chatzistergos, P., Sundar, L., Chockalingam, N., Ramachandran, A.: Differences in the mechanical characteristics of plantar soft tissue between ulcerated and non-ulcerated foot. J. Diabetes Complications **30**, 1293–1299 (2016)
11. Cheung, J.T.M., Zhang, M., Leung, A.K.L., Fan, Y.B.: Three-dimensional finite element analysis of the foot during standing - a material sensitivity study. J. Biomech. **38**, 1045–1054 (2005)
12. Gefen, A.: Plantar soft tissue loading under the medial metatarsals in the standing diabetic foot. Med. Eng. Phys. **25**, 491–499 (2003)
13. Armstrong, D.G., Lavery, L.A., Bushman, T.R.: Peak foot pressures influence the healing time of diabetic foot ulcers treated with total contact casts. J. Rehabil. Res. Dev. **35**, 1–5 (1998)
14. Robertson, D.D., Mueller, M.J., Smith, K.E., Commean, P.K., Pilgram, T., Johnson, J.E.: Structural changes in the forefoot of individuals with diabetes and a prior plantar ulcer. J. Bone Jt. Surg. Am. **84-A**, 1395–1404 (2002)
15. Tohno, E., Umemoto, T., Sasaki, K., Morishima, I., Ueno, E.: Effect of adding screening ultrasonography to screening mammography on patient recall and cancer detection rates: a retrospective study in Japan. Eur. J. Radiol. **82**, 1227–1230 (2013)
16. Wasadikar, A.P., Jadhav, M.B., Rote-Kaginalkar, V.J., Wasadikar, P.P., Jha, P.S.: Differentiation of solid breast masses into benign and malignant by using gray scale ultrasonography and strain elastography. J. Med. Sci. Clin. Res. **5**, 31456–31463 (2017)
17. Maurer, C.L., Sprigle, S.: Effect of seat inclination on seated pressures of individuals with spinal cord injury. Phys. Ther. **84**, 255–261 (2004)

18. Lung, C.W., Yang, T.D., Crane, B.A., Elliott, J., Dicianno, B.E., Jan, Y.K.: Investigation of peak pressure index parameters for people with spinal cord injury using wheelchair tilt-in-space and recline: methodology and preliminary report. Biomed. Res. Int. **2014**, 508583 (2014)
19. Lung, C.W., Hsiao-Wecksler, E.T., Burns, S., Lin, F., Jan, Y.K.: Quantifying dynamic changes in plantar pressure gradient in diabetics with peripheral neuropathy. Front. Bioeng. Biotechnol. **4**, 54 (2016)

Design of an Enhanced Disc Golf Game to Facilitate Players with Visual Impairments

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Abstract. Participation in recreational activities is important to maintaining a healthy lifestyle; however, obesity rates are climbing, particularly among individuals with visual impairments (VI). One of the contributing factors to the high obesity rates is the lack of accessible physical activities available for people with disabilities to participate in. Many of the current activities suggested to individuals with VI require teams and organization, and do not support inclusion between individuals with VI and those without. One solution to this is to create a mobile system for disc golf that facilitates accessibility for individuals with VI. Disc golf has become increasingly popular since its inception in the 1960s, and much of its popularity is likely due to its accessibility; with limited required equipment, free public courses, and a gentle learning curve for beginners, disc golf is an easy activity to become involved in. It would be an ideal activity to address physical activity and social needs for individuals with VI; however, the game is highly dependent on visual cues for locating goal points, avoiding obstacles, and finding one's disc. This project aims to extend accessibility of disc golf by designing a theoretical auditory notification and GPS mapping system. This system is intended to be integrated into existing disc golf courses without affecting how the game is currently played, and its implementation would allow both individuals with and without VI to play the game simultaneously with one another.

Keywords: Accessibility · Human factors · Outdoor recreation
Visual impairments

1 Introduction

Obesity is a growing epidemic worldwide, and obesity rates among people with disabilities are even greater than that of the general population. In the United States, 41% of adults with disabilities, compared to 25% of adults without disabilities, are considered to be obese [1]. One of the contributing factors to the obesity rate is the lack of physical activities available for people with disabilities to participate in. Studies conducted on

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physical activity for both children [2] and adults [3] with VI corroborate the general statistics for people with disabilities. In addition to fitness benefits, studies have found that individuals who are blind who participate in physical activities exhibit less involuntary behaviors, such as body rocking, and twisting of the head compared to individuals that are less active [4].

Participating in an active lifestyle has benefits that go beyond physical fitness; engaging in activities also provides an opportunity for social interaction. Although studies have shown that school-age people with VI do not report significant levels of loneliness [5], older adults do, and few studies have been conducted on social isolation among working-age adults [6].

Sports organizations and activities have been created to accommodate participants with VI. These activities offer social engagement and physical activity; however, they often require coordination with groups of people, require specific recreational areas, and have limited opportunities for inclusive participation. In order to better help individuals achieve their fitness and recreation goals, an ideal activity would be easy to learn, require little specialized equipment or associated costs, and allow the player to participate spontaneously.

Disc golf has become increasingly popular since its inception in the 1960's and much of its popularity is likely due to it accessibility; with limited required equipment, free public courses, and a gentle learning curve for beginners, disc golf is an easy activity to become involved in. Disc golf also has simple rules: the player starts at a tee zone and throws their disc toward a goal basket, and the objective is to get the disc from the tee zone to the goal in as few throws as possible. After each throw, if the player did not make it in the basket, he or she must throw the disc again from that location. Like traditional golf, disc golf courses are usually comprised of 18 holes. This presents the opportunity for the player to exercise by walking the course. The game can be played individually or competitively in a group. Disc golf would be an ideal activity to address physical activity and social needs for individuals with VI; however, the game is highly dependent on visual cues for locating goal points, avoiding obstacles, and finding one's disc. Accessibility of disc golf can be extended to users with VI by creating a mobile system comprised of auditory notifications and GPS mapping.

The auditory notification system focuses on embedding sound emitting beacons on the tee points, goal baskets, and discs to aid players with VI in target location. These beacons will be controlled by an accessible mobile application. The system is intended to be integrated into existing disc golf courses without affecting how the game is currently played. The implementation will allow individuals with VI and individuals without to play the game simultaneously with one another.

2 Human Factors Considerations

While the entire device is designed to keep in mind both human factors as well as optimization of the gameplay experience, the two main aspects that take human factors into account considerably well are the audio feedback and assistive touch gestures in the mobile application.

There are two sensory alternatives to sight that can be used by people with visual impairments to help them navigate and locate objects: audio feedback and haptic feedback. While a haptic feedback experience can be more personalized, i.e., a wearable device, this can affect cosmesis and outward appearance as well as the feelings of the user who is wearing the device. For example, a user may not want to wear a haptic belt because it adds bulk to their figure and can be seen by other people. Instead, the chosen method for guiding users through the disc golf game is audio feedback. Audio cues are relatively easy to implement into any mobile application or device, and they are able to be turned on and off at the user's command. And, because of their implementation into the design, the cosmesis of the discs and phones will not change.

Next, the mobile application is designed to only require simple touch gestures on behalf of the user. Swiping side to side on the screen will turn the beeping of the disc on or off and swiping up and down would turn the beeping of the target on or off. By utilizing simple gestures rather than points of contact on the screen such as specific buttons or targets that the user would press, the design eliminates most error associated with missing the buttons due to lack of visual feedback.

2.1 System Requirements

The entire modified disc golf game and accompanying mobile application must operate under a set of system requirements that will determine whether the final design is

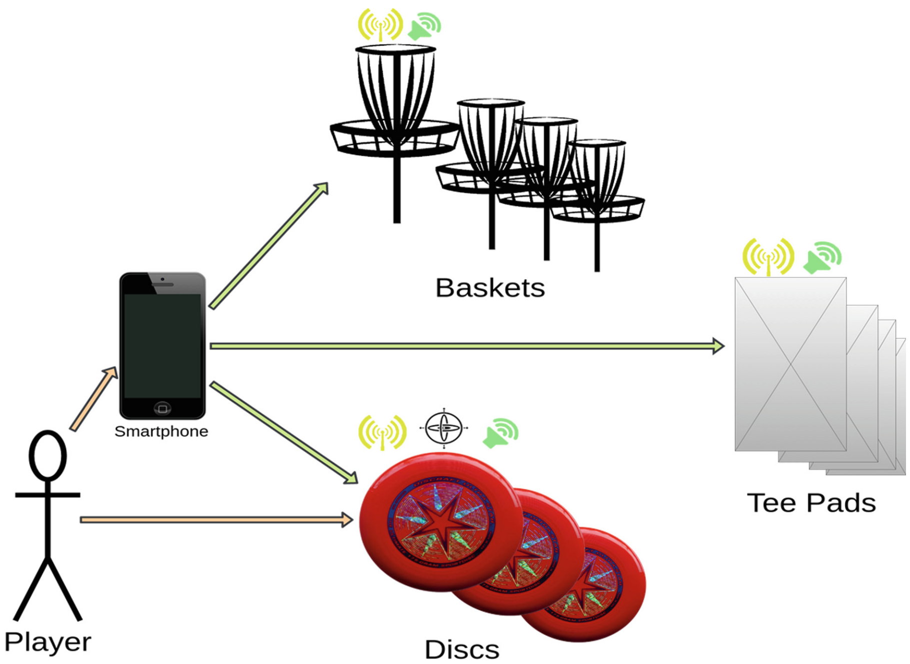

Fig. 1. Overview of the disc golf system, including the user, a smartphone, baskets, tee pads, and discs.

successful or not. First, the mobile application must recognize and represent the map of the disc golf course. This will be done using existing GPS navigation capabilities. Additionally, the mobile application must be user friendly and may only require minimal training. Next, the device added to the Frisbee disc that will emit noise for users to determine its location must not alter the disc's weight, dimensions, or flight capabilities. If the device is too heavy or large, it will have undesired effects on how the disc flies and this could detract from the gameplay experience. Finally, the monetary cost of the system must be reasonable to users so as not to make the game inaccessible to anyone for financial reasons. Figure 1 illustrates an overview of the entire modified disc golf system.

2.2 Operational Need and Concept

Exploitable Technology. Existing technology capabilities that will be taken advantage of for design of this system includes Bluetooth, GPS navigation, mobile phone applications, and audio feedback devices. The combination of these four existing pieces of technology for the purpose of playing disc golf is a novel concept.

Constraints and Deficiencies. There are three potential constraints to be mindful of throughout the duration of this system's creation. These constraints include the requirement of additional training to learn how to use the system in addition to learning the rules of the game, the weakening of audio cues in longer distances, and the possibility of the addition of a device to the Frisbee disc affecting its flight trajectories and therefore, gameplay.

Major Functions of User. The user of this system will be allocated four major functions: locating the tee pad, locating the basket, locating the disc, and throwing the disc.

Major Functions of System. The system will be allocated two in-field functions of generating an auditory cue for the tee pad, basket, or disc and generating auditory feedback of the flightpath of the disc while it is in flight. The system will also be allocated one one-phone function of providing spatio-directional information to the user on the locations of the tee pads, baskets, and discs.

2.3 Characteristics of Potential Users

The system design allows for a wide variety of potential users to play the enhanced disc golf game, and the specific characteristics of potential users are as follows:

- User may have a visual impairment.
- User must not have hearing loss.
- User must be capable of cognitively understanding the rules of disc golf.
- User must be able to throw the Frisbee disc.
- User might be with other impairments.
- User must be able to travel around the playing course, either with or without assistance.

2.4 Function Flow Analysis

Figure 2 shows a flowchart of the functions performed by the user of the system, beginning with going to the tee pad and opening the mobile application. The user will then use the application to request the auditory cues, which will assist them in locating the target. The user will then throw the disc, and, if necessary, request additional auditory cues to locate the disc, pick it up, and begin the process again. The function flow will end when the user has successfully hit the target basket with their disc.

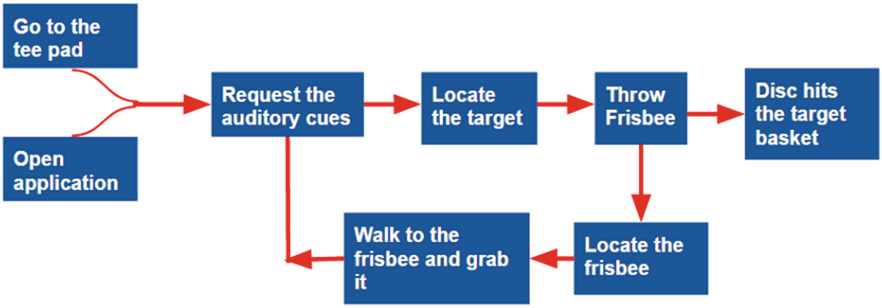

Fig. 2. Function flow analysis of functions executed by the user of the system.

3 Prototype

In order to test the system concept, a prototype disc was constructed. The prototype consisted of a Bluetooth tracking tag attached to a disc golf frisbee. The tracking tag used for the prototype was the TrackR Bravo (TrackR; Santa Barbara, CA). The TrackR Bravo tag connects to a mobile phone through Bluetooth and by using the accompanying mobile application, the user can trigger a sound beacon on the tag. The TrackR Bravo also provides GPS tracking so that the mobile application can record the location of the

Fig. 3. Innova Disc Golf Wraith Driver disc top view (left) and bottom view with attached Bluetooth tracker (right).

tag when it syncs with a phone using the application. The tag weighs 8.5 g, and is shown in Fig. 4.

Fig. 4. TrackR Bravo Bluetooth-enabled wireless tag.

The TrackR Bravo was attached to an Innova Disc Golf Wraith Driver (Innova Disc Golf; Ontario, CA) with adhesive tape, as shown in Fig. 3. The disc is designed to maximize distance. Prior to attaching the tracker, the disc weight was 171 g. The combined weight of the disc and tracker was 179.5 g, which is at the upper limit of the weight of manufactured disc golf discs as determined by the Professional Disc Golf Association (PDGA) [7].

3.1 Evaluation of Prototype

The prototype was evaluated for proof of concept by conducting tests in an open-air field. The goal of the evaluation was to test the difference in flight distance and integrity of the disc with and without the TrackR device. Distance was measured in meters. Flight integrity was based on observation of disc wobble and flight trajectory. After test-throwing of the prototype, the range of the tracking device was evaluated. The maximum range of where the device's sound was audible was tested along with the limits of the Bluetooth connectivity with the tag.

3.2 Results of Evaluation

Five forehand and five backhand throws were recorded for both conditions: disc with the tracking tag and disc without the tracking tag. The mean distances of each throw are reported in Table 1 below. For backhand distance, there was little difference between the mean of throws with or without the tracker. Forehand throws show a 5.2 m increase in distance with the tracker attached. The increased distance is likely do to the increased weight. The disc was noticeably heavier after the tracker was attached.

Table 1. Results of test-throwing the disc before and after modifications.

	Without TrackR	With TrackR
Weight	171 g	179.5 g
Mean backhand distance	40.2 m	40.9 m
Mean forehand distance	54.6 m	59.8 m

Based on observation, there was no discernible difference in flight integrity when the tracker was attached. This reflects that attaching the tracker did not alter the balance or aerodynamics of the disc.

Tests on the range of the tracker were limited. It was found that neither the sound nor the Bluetooth range were sufficient for functional testing. In the outdoor conditions, the sound was only audible up to 18 m. The Bluetooth range was limited to 11 m when the disc was on the ground.

3.3 Limitations and Proposed Improvements

The testing was limited by inconsistencies in the throwing conditions. The test throws were conducted by a single human participant under outdoor conditions. Because of this, changes in results due to wind fluctuation and inconsistent throws by a human user cannot be ruled out. Additional testing should be conducted by a mechanical throwing device under controlled conditions. The number of trials should also be increased.

Due to the limited sound and connectivity functions of the TrackR, the prototype was not tested with participants from the target user group of users with visual impairments. Custom hardware would be required for the next iteration of the device. This hardware would need to have more powerful sound capabilities along with use of a different wireless communication technology. The next iteration could instead utilize Wi-Fi technology by enabling the user's phone as a wireless hotspot in order to increase the communication distance between the phone and the device embedded in the disc.

After testing the prototype, it was evident that some important components could be added to the system. One of these components is performance feedback. While users without VI can see and compare their performance with their past throws and other players' performance, this is not possible for users with VI. This results in slower motor learning [8] and less motivation for this physical activity. Therefore, auditory performance feedback could be provided to the players after each throw by using the data from their previous performance and other players' performances, in the form of two distinct two-tone sounds played on their cellphones. One of the sounds would be auditorily pleasing, which would signal positive feedback. The other sound would be auditorily unpleasant and would signal that the person is not progressing.

Additionally, there are two different gameplay options that could be offered in the app depending on the number of players in the game: one option for a single player and a second option for multiple players. In the first option, the app would calculate the average distance of the player's previous throws in the same state (from the same tee pad to the same goal) and let them know if their current throw is closer to the goal (better performance) or not. They will always receive positive feedback for their first throw in every state, so long as they are progressing towards the basket. For the second option, after all the players are finished throwing their discs, the app would first calculate the distance between all players' discs and the basket. Then, the app could obtain information from other players' cell phone applications and begin comparing their performance.

4 Conclusion and Future Work

The main objective of this project was to design an extension to the disc golf game so that it is accessible to those with visual impairments. The growing literature showing that social integration and recreational activity is essential to the health and wellness of people with visual impairments, was the motivation for this project. So far, the high-level system has been designed (Fig. 1) along with the operational need and concept, requirements analysis, functional flow, and a task analysis. Future work includes designing a circuit-level model of the modules to be placed on the disc and a mobile phone application, as well as preliminary testing of those modules and the application. The wireless connectivity modules for the baskets and the tee pads must also be designed and tested. Because the wireless connector modules will feature the same basic functionality, a single design will be employed for the disc, baskets, and tee pads. Then, further testing can be conducted with a group of users without VI as well as a group of users from the target population of users with VI.

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References

1. Kraus, L.: Disability Statistics Annual Report, Durham, NH (2015)
2. Augestad, L., Jiang, L.: Physical activity, physical fitness, and body composition among children and young adults with visual impairments: a systematic review. Br. J. Vis. Impairment **33**(3), 167–182 (2015)
3. Marmeleira, J., Laranjo, L., Marques, O., Pereira, C.: Physical activity patterns in adults who are blind as assessed by accelerometry. Adap. Phys. Act. Q. **31**(3), 283–296 (2014)
4. Gaetano, R., Gaetano, A., Filippo, G.P.: Effects of physical activity and sports in the reduction of stereotypy in blind subjects. Sport Sci. **8**, 52–55 (2015)
5. Jessup, G., Bundy, A., Broom, A., Hanock, N.: The social experiences of high school students with visual impairments. J. Vis. Impairments Blindness **111**, 5–19 (2016)
6. Hodge, S., Eccles, F.: Loneliness, social isolation and sight loss. In: Thomas Pocklington Trust, London (2014)
7. PDGA Approved Disc Golf Discs. https://www.pdga.com/documents/pdga-approved-discs
8. Willingham, D.B.: A neuropsychological theory of motor skill learning. Psychol. Rev. **105**(3), 558–584 (1998)

Measuring Tactics of Taking the Ball Away from Defenders in the Japanese Football League

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Abstract. Football tactics continue to evolve; such as individual play, total football, one-to-one defense, zone defense, pressing, Gegen (counter) press, positioning soccer, reaction football and vertical fast attack. Among these tactics, the simplest and easy-to-score attack is to take the ball from defenders at a high position. The takeover of the ball is a play, which will be the beginning of the attack for the offense, so taking the ball away is important for any teams in order to win and enter into the top group. In this research, we focus on this tactic and consider effective tactics in contemporary football by comparing top, middle and lower teams of the Japanese Football League.

Keywords: Tactics · Japanese Football League · Ball positioning data

1 Introduction

Soccer, *i.e.* football, tactics are constantly evolving, and many new tactics have been created so far as well. For example, total football is a footballing tactic in which any player can assume any role. Only the goalkeeper, who functions as the ultimate defender, plus ten outfield players, are tied to their position [1]. All players increase their ball dominance with the total football tactic and then pass the ball; this method demonstrates awareness of both attack and defense. In the possession football style, the team simply passes the ball between each other. Among the myriad of tactics, the ones that win are those that change according to the opponent's tactics and player's level, but the attacks that score easily tend to be high in tactics and levels.

In the Japanese football league ('J-League'), Kashima Antlers won the J1 league 2016 season. The J1 league is the top division of the Japan Professional Football League, and is the top professional association football J-League in Japan. Numbers of Kashima's tactics related "taking ball away from the opponent," such as the number of tackles, the number of ball retraction in the opponent team, and Kashima had the highest number of taking the ball back within 5 s in that season. In addition, Blaublitz Akita of J3, a third-tier professional association football league in Japan, controlled the 2017 season with aggressive press from the front, expected to take a ball at a high position. In this way, the usefulness of taking balls away in actual games witnessed.

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In this study, we focus on players' "intercepting a ball or a pass" or "taking a ball away" to start a counter attack, which is considered as an important play for both offensive and defensive positions. We compare the top, middle and lower teams in the J1 2016 season to find out the effective tactics in the contemporary football.

2 Literature Review

There are some literatures that analyze interception and possession balls in various sports. As for football, Carmichael et al. [2] measured team performance in a match of English Premiership Football, in terms of the final score expressed as the goal differential (positive if observed team won, negative if lost and zero if result is a draw). They found the more explicitly 'defensive' plays, which relate to tackling, clearances, blocks and interceptions, have the predicted positive signs and are highly significant. Constantinou et al. [3] predicted the outcome of matches by using possession rates of different teams and other historical statistics to develop probabilistic models. Using data from five European leagues, UEFA and FIFA tournaments, Collet [4] found that while possession time and passing predicted aggregated team success in domestic league play, both variables were poor predictors at the individual match level once team quality and home advantage was accounted for. Hirotsu and Wright [5] utilized information of the English Premier League in the 1999–2000 season not only about the transition rates of scoring and conceding goals but also the rates of gaining and losing possession, using explanatory variables of home advantage, offensive strength and defensive strength, which is a very important consideration in any football match. Higuchi et al. [6] analyzed the change in the position and number of times taken by training the "play centroid", for a team intercepting a ball at a high position in college soccer. They integrated their visual evaluations by means of "play centroid", which is a method of converting visual evaluations of performance into quantitative data that can then be analyzed objectively. Tamura et al. [7] analyzed the classification of the attacks after the ball were taken and revealed that swift attacks succeeded when the capture position is higher. Gama et al. [8] analyzed 13,958 passes and 7,783 collective offensive actions of the Portuguese Premier League season 2010/2011, and found that the ball possession during a football match endows the team with a larger domain in terms of game actions, and the ball possession does not significantly influence over outcomes of the game.

In basketball, there is some research on a turnover, which occurs when a team loses possession of the ball to the opposing team before a player takes a shot at his team's basket. The value of shooting skills in basketball depends upon the team's ability to acquire the ball via rebounds or turnovers [9, p. 382]. The results of Berri [10] indicated the importance of ball handling, especially turnovers by both a player and the opponent, have a greater marginal impact than any factor but three point field goals made and offensive rebounds. A player's contribution to team success depends most heavily on his accumulation of rebounds, avoidance of turnovers, and shooting efficiency. Yanagihara et al. [11] analyzed turnovers of 50 matches of 16 teams in Kanto University Basketball League in 2009. They found that in case of patient build-up play, it is disadvantageous for the defense by pass mistakes; however, defensive formations can work in their favor against the opponent's cutting. In case of fast break, the defense can keep their formation, even if a ball taken away.

In hockey, tactics could be the difference between winning and losing. Kobayashi [12] analyzed the hockey game, and concluded that the wining team had more balls in attack zones as well as midfield zones compared to other teams, and it was effective to take a ball at the high position.

3 Conceptual Models for Ball Interceptions

We define “a ball gain” when the ball gain happened after the ball lost and the ball gain continued, and calculate “number of all interceptions,” “average time for interception,” “average distance for interception,” “number of interceptions within x seconds,” “number of interceptions within x meters “and “an intercepted area” where we divide the football pitch by 6 × 4. Figure 1 shows a conceptual model for a ball interception based on those factors. We also define the ball gain after the ball lost, then shoot a goal as “a good ball gain,” and calculate number of ball interceptions led to shoot goals, and number of players involved at the time of the ball interceptions (see Fig. 2).

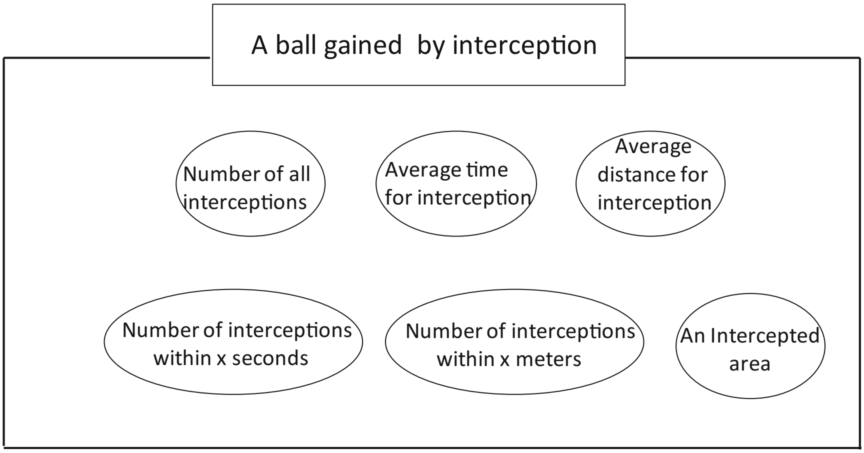

Fig. 1. A conceptual model for ball interception

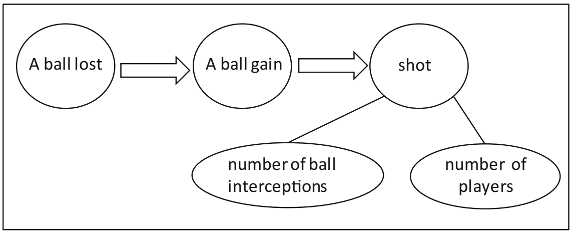

Fig. 2. A good ball gain model

4 Data

Data Stadium Inc., Japan's leading sports information provider, prepared the dataset. New Area Integration Research Project (Social Communication, Joint Support-Center for Data Science Research, and Human and Social Data) of the Research Organization of Information and Systems financially supports this project.

There are two kinds of dataset: (1) "ball touch data" representing the play when the player touches the ball, and (2) "tracking data" representing the coordinate data of the player. From the ball touch data, we created three dummy variables. "A ball lost" which returns 1 (one) when losing the ball, and "a ball gain" which returns 1 (one) when the ball is acquired, "shoot" returns "1" when the player shot. There is also a variable for coordinates of the ball on the pitch, as well as a variable for showing the area ball interception played as "HOT ZONE 4–6" where we divide a pitch field by 4×6. From the tracking data, we use "coordinates of players," representing the coordinates of players on the pitch.

Out of 18 teams belonging to J1 League in the 2016 season, we have selected eight teams and ranked the champion Kashima Antlers (Kashima), 2nd Urawa Reds (Urawa), and 3rd place Kawasaki Frontale (Kawasaki) as the top group. We selected 9th FC Tokyo (Tokyo), 10th Yokohama F Marinos (Yokohama) as the middle tier group, and lastly, 16th Nagoya Grampus (Nagoya), 17th Shonan Bellmare (Shonan) and 18th Avispa Fukuoka (Fukuoka) as the lower tier group. We focus on five games for each team, totaling 40 games in this study.

4.1 Descriptive Statistics

4.1.1 Number of Entire Interceptions

The total number of interceptions of each team's five games is shown in Fig. 3. The total number of Kajima's interceptions was 301, followed by 277 of Tokyo and 276 of Shonan. Regardless of the ranking, teams with a larger number of interceptions is not based on their final rankings, but is thought to be due to the tactics of each team.

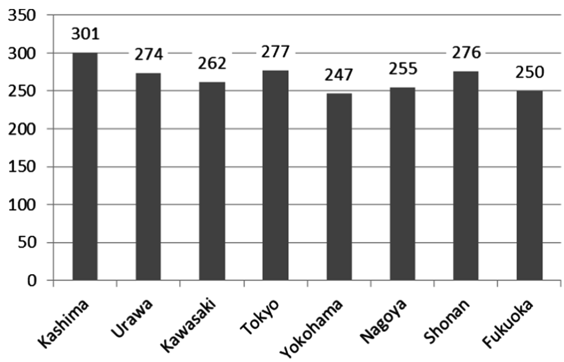

Fig. 3. Total number of ball interceptions

4.1.2 Average Time and Distance for Interceptions

Let assume the absolute time at the ball gain minus the absolute time at the ball lost as "the interception time," and the interception time divided by the total number of interceptions as "average interception time."

$$\begin{aligned}\text{The interception time} &= \text{the absolute time at the ball gain} \\ &\quad - \text{the absolute time at the ball lost}\end{aligned} \tag{1}$$

$$\text{The average interception time} = \text{the interception time}/\text{total number of interceptions} \tag{2}$$

Next, let assume the coordinates when the opponent takes the ball from the own team as (X_L, Y_L), and the coordinates when own team takes the ball from opponent as (X_G, Y_G). The distance from the origin, located at a center mark of the pitch, are calculated by formulas (3) and (4). Then, we calculated the distance between the coordinates taken the ball by opponents and the coordinates taken the ball by own team using Pythagorean theorem (see Fig. 4). The distance is calculated by Formula (5), and Fig. 1 shows the outline of distance calculation.

$$Max(X_L, X_G) - Min(X_L, X_G) \tag{3}$$

$$Max(Y_L, Y_G) - Min(Y_L, Y_G) \tag{4}$$

$$\sqrt{(Max(X_L, X_G) - Min(X_L, X_G))^2 + (Max(Y_L, Y_G) - Min(Y_L, Y_G))^2} \tag{5}$$

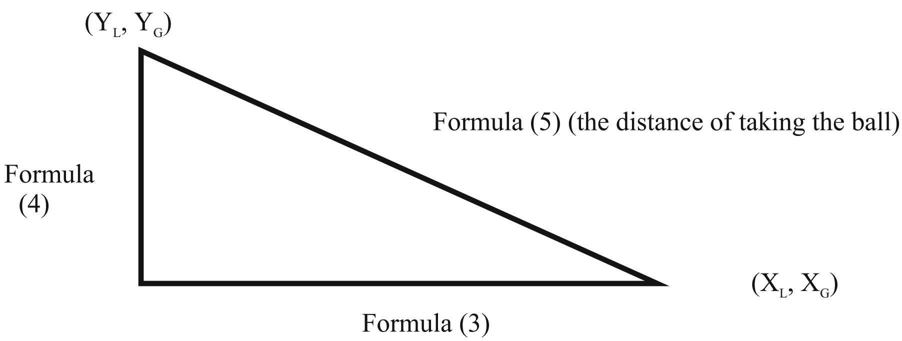

Fig. 4. Pythagorean theorem

A list of the average intercepting time of each team shows in Table 1, and that of the average intercepting distance shows in Table 2.

Table 1. Average interception time

Team name	Average time [s]
Vissel Kobe	28.0
Sanfrecce Hiroshima	28.3
Kashiwa Reysol	29.7
Omiya Ardija	29.8
Vegalta Sendai	30.6
Shonan Bellmare	31.0
Gamba Osaka	32.3
Yokohama F-Marinos	33.3
Kawasaki Frontale	33.9
Kashima Antlers	34.5
Urawa Red Diamonds	35.2
Sagan Tosu	35.6
FC Tokyo	35.9
Albirex Niigata	36.0
Avispa Fukuoka	36.1
Jubilo Iwata	39.9
Ventforet Kofu	41.1
Nagoya Grampus	44.3

Table 2. Average interception distance

Team name	Average distance [m]
Gamba Osaka	33.7
Jubilo Iwata	33.9
Omiya Ardija	35.4
Sanfrecce Hiroshima	36.0
Albirex Niigata	36.8
Vissel Kobe	37.0
Kashima Antlers	37.0
Vegalta Sendai	37.2
Shonan Bellmare	37.4
Kawasaki Frontale	37.4
Kashiwa Reysol	37.6
Yokohama F-Marinos	38.3
Nagoya Grampus	38.3
Avispa Fukuoka	38.4
FC Tokyo	38.5
Ventforet Kofu	38.5
Urawa Red Diamonds	39.5
Sagan Tosu	40.8

Looking at the J1 league as a whole, the top tier group of Kashima and Kawasaki are located in the middle of time and distance, and it shows that time and distance do not depend on the final rankings as well as the total number of interceptions. In addition, the lower ranked Nagoya and Fukuoka are located lower in both time and distance, while another lower ranked Shonan is located in the top sixth for time and middle for distance. It is conceivable that even if the time is too quick or too late, it will not be effective interceptions. The physical strength of the athlete decreases, if he keeps faster moves all the time, and it is important to retire to his own territory from time to time.

4.1.3 Interceptions Within x Seconds

The number of times to intercept a ball within x seconds after losing the ball calculated, and the ratio to the total number intercepted shows in Table 3. Kashima protrudes and takes a higher percentage of interceptions within 6 s. In addition, while the top team gets faster, the lower team takes more time for interception, although intercepting time of some teams, such as Kawasaki (3rd) or Shonan (17th), has no impact on their final rankings.

Table 3. Percentages of interception within x seconds

	≤ 10 s	≤ 8 s	≤ 6 s	≤ 4 s	≤ 2 s
Kashima	36.2%	33.9%	28.2%	22.9%	15.9%
Urawa	39.4%	32.5%	21.2%	10.9%	1.8%
Kawasaki	32.4%	27.1%	18.7%	8.8%	1.5%
Tokyo	34.7%	29.6%	20.6%	8.7%	1.4%
Yokohama	33.6%	25.9%	16.2%	7.7%	2.0%
Nagoya	30.2%	25.9%	18.8%	7.5%	2.0%
Shonan	37.0%	27.9%	19.9%	8.7%	2.5%
Fukuoka	36.4%	28.4%	18.4%	6.8%	2.4%

4.1.4 Interceptions Within x Meters

Table 4 shows the ratio of the distance to the total number of interceptions, after calculating the number of times to intercept a ball within x meters after losing the ball. Kajima's interceptions are increasing in proportion as well as time, but since the upper team does not take it in a short distance and the lower team sometimes intercepted within a short distance, it implies that a difference in whether or not to go and get the ball aggressively from the front.

Table 4. Interceptions within x meters

	≤ 15 m	≤ 12 m	≤ 9 m	≤ 6 m	≤ 3 m
Kashima	20.6%	16.6%	10.6%	4.7%	3.0%
Urawa	15.0%	12.0%	8.4%	3.6%	1.5%
Kawasaki	12.6%	10.7%	6.5%	3.4%	1.1%
Tokyo	17.0%	11.6%	7.2%	3.2%	0.7%
Yokohama	15.4%	10.5%	5.7%	3.2%	1.2%
Nagoya	17.3%	13.3%	9.0%	5.5%	2.0%
Shonan	15.2%	11.2%	6.2%	3.6%	1.4%
Fukuoka	12.8%	10.8%	6.8%	2.4%	0.8%

4.1.5 Intercepted Areas

We calculate the ratio of area intercepted and applied it to the pitch divided into 4×6 to visualize the area at the time of interceptions (see Table 5). Every team had intercepted balls a lot (where more red areas) before their own goal and there was few interceptions (where more green areas) on the front line, but only Kashima got scattered interceptions in all areas. As mentioned earlier, Kashima is quick to get a ball back from the opponents, and as a result, Kashima can take a ball back before attacked by opponents in front of their own goal area.

Table 5. Intercepted areas

	Kashima Antlers				Urawa Red Diamonds				Kawasaki Frontale				FC Tokyo			
The Opponent Goal	4.33%	3.97%	7.58%	7.94%	1.44%	0.36%	0.36%	1.44%	0.00%	0.00%	0.36%	0.36%	0.00%	0.36%	1.08%	0.36%
	6.14%	4.33%	4.69%	6.86%	1.81%	2.89%	2.17%	2.89%	1.08%	2.17%	2.17%	1.44%	0.72%	1.44%	2.89%	0.00%
	3.25%	5.05%	5.78%	7.58%	2.53%	5.42%	5.05%	3.25%	2.89%	4.33%	2.89%	1.08%	2.53%	5.78%	7.22%	3.25%
	5.05%	2.53%	6.50%	3.61%	3.97%	5.78%	8.30%	1.44%	4.33%	6.86%	7.58%	3.97%	3.97%	6.86%	5.42%	2.17%
	4.69%	3.25%	3.61%	3.61%	3.97%	8.66%	10.47%	4.33%	5.42%	6.50%	9.03%	3.25%	5.78%	12.64%	8.30%	4.69%
The own Goal	0.72%	2.17%	4.69%	0.72%	1.08%	8.66%	11.55%	1.08%	2.53%	7.94%	13.72%	4.69%	2.53%	8.30%	10.47%	3.25%

	Yokohama F-Marinos				Nagoya Grampus				Shonan Bellmare				Avispa Fukuoka			
The Opponent Goal	0.00%	0.36%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.36%	0.00%	0.00%	0.36%	0.72%	0.00%
	0.36%	1.08%	2.17%	2.17%	0.72%	2.89%	0.72%	1.81%	1.44%	1.08%	2.53%	3.25%	1.08%	1.08%	1.81%	0.72%
	3.25%	2.89%	3.25%	1.08%	2.17%	2.53%	3.97%	1.81%	2.89%	3.97%	5.05%	4.33%	1.44%	3.25%	3.25%	3.61%
	2.17%	4.33%	5.05%	3.61%	2.17%	7.94%	4.69%	1.81%	3.25%	6.86%	6.14%	5.05%	3.97%	5.42%	6.50%	2.17%
	4.69%	9.75%	11.91%	5.05%	6.50%	11.55%	8.66%	2.53%	4.33%	8.66%	7.94%	4.33%	5.42%	10.11%	10.83%	3.61%
The own Goal	0.72%	7.94%	15.16%	2.17%	2.53%	10.47%	14.08%	2.53%	3.97%	11.91%	10.11%	2.17%	3.25%	10.11%	10.47%	1.08%

4.1.6 Number of Interceptions Led to Shoot a Goal

Figure 5 shows the number of interceptions which led to shoot a goal. In calculating "a good ball gain," which the ball gain after the ball lost, and then shoot, we calculated the number of "a good ball gain" for each team. Figure 4 shows that Kawasaki and Urawa are prominent. It implies that these two teams have increased ball possessions and have successfully score goals without taking the ball away by the opponents. Kashima, which was the faster team in terms of interception, had almost the same number of good ball gains to other teams. Even in the top three teams, it seems that Urawa, Kawasaki, and Kajima adopt different tactics.

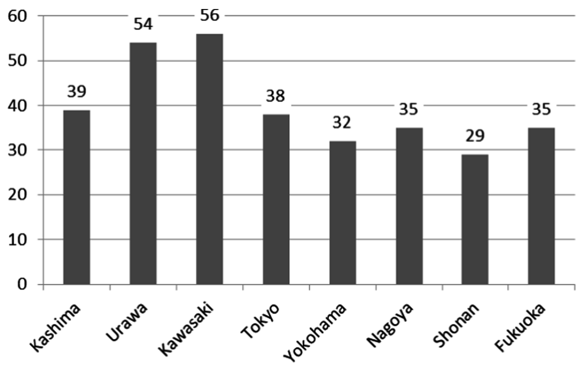

Fig. 5. Number of interceptions led to shoot a goal

4.1.7 Number of Players at the Time of Interceptions

We calculated numbers of both own team and opponent team at the time of interceptions led to shoot. Figure 6 shows the number of players of own teams and opponents on interceptions. It is more likely that they have chance to score with 6 to 7 players of their own, and 8 to 9 players of the opponents. In other words, the interceptions near the opponents' goal are likely to lead to shooting, compare to their own goal areas.

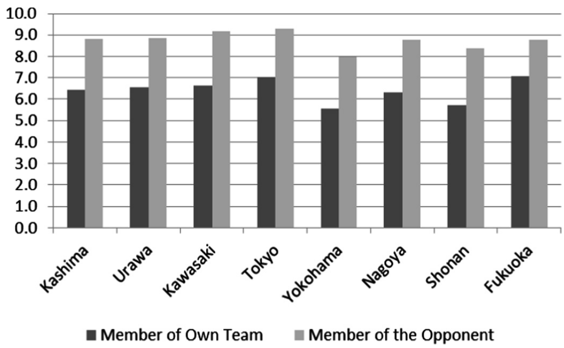

Fig. 6. Number of players at the time of interceptions

Figure 7 shows the number of own team members who intercepted balls. While the most of teams had a rate of 50 to 60% when they had less than six players for the time of interceptions, those of Tokyo and Fukuoka had less than 40%. It implies that there are more interceptions occurred when there are more own team members around.

Figure 8 shows the number of opponents' members who intercepted balls. It is clear that the proportion of Kashima for less than six people is significantly higher than other teams. It implies that Kashima had tactics to shot a goal when there are few opponents, while they hold on to the ball when there are many opponent players around.

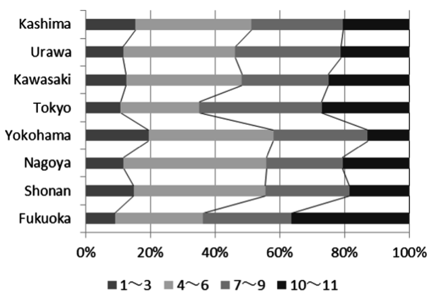

Fig. 7. Number of players of own team at the time of interceptions

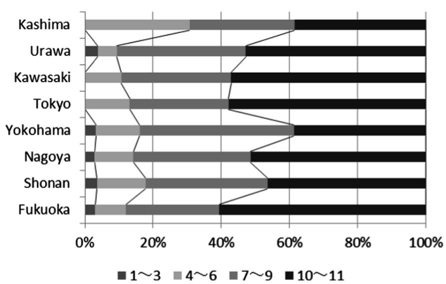

Fig. 8. Number of players of opponent teams at the time of interceptions

5 Cluster Analysis

In order to find groups in data, we conducted hierarchical cluster analysis. Variables in this analysis are the total number of interceptions, average time, average distance for interceptions, interceptions within six seconds, interceptions within 12 m, Area A, Area M, Area D, number of interceptions led to shoot a goal, 3 own team members, 6 own team members, 9 own team members, 11 own team members, 3 opponents, 6 opponents, 9 opponents, and 11 opponents. We randomly selected six seconds and 12 m among x seconds and x meters, respectively. Where in the field the ball is located upon interceptions, Area A is an attacking third, Area M is a middle third, and Area D is a defending third.

The dendrogram on Fig. 9 is the result of the cluster analysis.

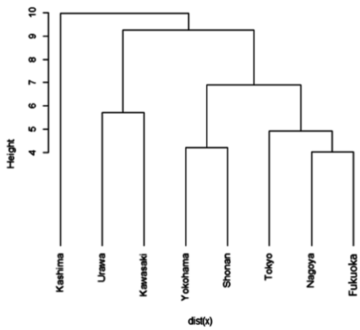

Fig. 9. The result of cluster analysis

From the results, we had three major groups; a group of “Kashima, Urawa and Kawasaki,” that of “Yokohama and Shonan,” and that of “Tokyo, Nagoya and Fukuoka,” and each group has similar characteristics. Because the results of the cluster analysis indicate the same grouping according to the final ranking, the characteristics seen in the upper teams could consider as the effective tactics in the modern football in Japan.

6 Principal Component Analysis

We performed principal component analysis (PCA) by using the same variables as the cluster analysis. PCA reduces the dimensionality of data by replacing several correlated variables with a new set of variables that are linear combinations of the original variables. The factor scores for the first two components are given in Table 6. The plot of the data in the space of the first two components, with the points labelled by the name of corresponding variables is shown in Fig. 10.

The first principal component is strongly correlated with four of the original variables. Since the first principal component has large positive association with “Area D”, “average interception time”, “3 opponents”, and “average interception distance,” and has large negative association with “interceptions within 12 m”, “Area A”,” the total number of interceptions”,” Area M”. We interpret the first PCA as “the speed of transition”. The second principal component has large positive associations with “number of interceptions led to shoot a goal,” and number of both own team and opponent team. Because it shows that interceptions over a wide area which often leads to a shoot, we interpret the second principal component as “possession of ball”.

Table 6. The loadings of the variables on the first two components

Variables	PC1	PC2
The total number of interceptions	−0.35926	0.07813
Average time for interceptions	0.09788	0.00040
Average distance for interceptions	0.24573	0.08620
Interceptions within six seconds	−0.37878	0.05576
Interceptions within 12 m	−0.36161	0.00047
Area A	−0.37044	0.00655
Area M	−0.28736	0.14992
Area D	0.37098	−0.03159
Number of interceptions led to shoot a goal	0.00721	0.40642
Average number of own team members in attack direction	−0.00577	0.23377
Average number of opponents in attack direction	−0.06128	0.33221
3 own team members	−0.09121	0.21947
6 own team members	−0.00265	0.28892
9 own team members	−0.01438	0.38976
11 own team members	0.02917	0.35823
3 opponents	0.20298	−0.06416
6 opponents	−0.03631	0.18196
9 opponents	0.25500	0.25275
11 opponents	0.22033	0.34155

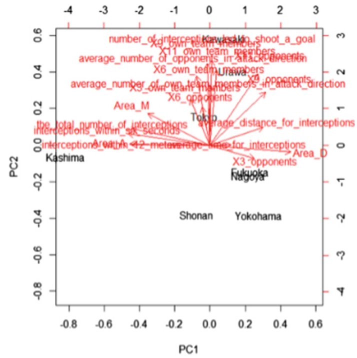

Fig. 10. The result of principal component analysis

7 Discussion

The loading plot visually shows the results for the first two components (see Fig. 11). The horizontal axis expresses “the speed of attack switching”, where the switch is slower as it is larger in the positive direction, and the switch is faster as it is larger in the negative direction. The vertical axis expresses “the ball dominance”, where the greater the positive direction, the more possession increases ball domination and the larger the negative direction, the stronger defenses are.

Teams assemble from behind (hereinafter, call as “rear assembly type”) are seen in the first quadrant. Those teams take time to change in offense and defense and gain a possession. Teams in the second quadrant seem to change in offense and defense quickly, and takes a possession. That is, even if the opponents take their balls away, the distance between players are close enough to cover and pass the ball to each other. It implies that teams in this area are those with a high compactness (hereinafter, call as “compact type”). Teams in the third quadrant seem to change in offense and defense quickly, and have a strong defense. It implies that teams in this area attacking with impregnable defense and quick offense (hereinafter, call as “impregnable defense & quick offense type”). Teams in the fourth quadrant seems to take time to change in offense and defense with impregnable defense (hereinafter, call as “fortify the defense type”), that consolidates the defense of own team and waits for chance to attack.

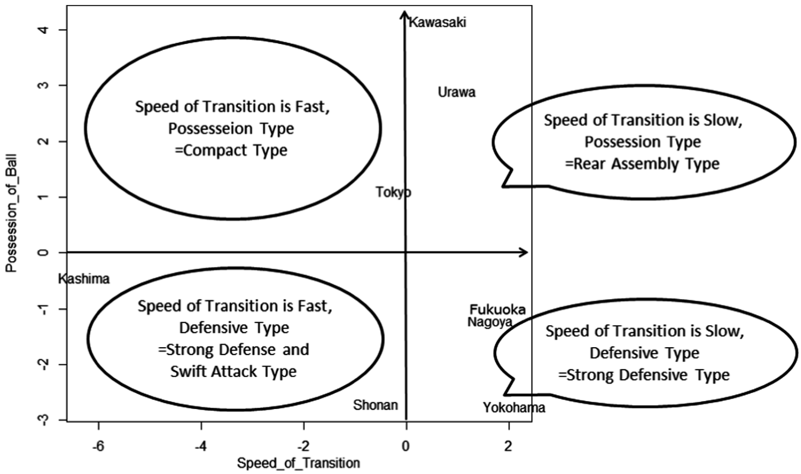

Fig. 11. Interpretations of principal component analysis for each team

Teams in the top tier group tend to change in offense and defense quickly, and aggressive on possession. They are considered as the “compact type” in which is an effective tactic to be the top tier. On the other hand, although the lower-tier teams are taking “impregnable defense” formation, they are in a lower tier group because their defense is passive rather than active using press back. For example, Yokohama, “fortify the defense type”, often takes away balls when there are fewer team members and opponents than the number of players at the time of interceptions. Since they are actively defending against their opponents, they are ranked in the middle tier group.

8 Conclusion

In this research, we focus on "intercepting a ball or a pass" or "taking a ball away" to consider effective tactics in modern football.

Through various analyses, we could conclude that tactics to speed up to change in offense and defense and enhance possessions are effective. In addition, in order to carry out this tactics, it is necessary to shorten the distance between the players, bring the distance between the defense line and the front line closer, and increase the compactness, rather than separating offense and defense. In any case, it is important for teams to have consciousness that offence and defense should be united in order to win.

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References

1. McNulty, P.: Johan Cruyff – The man who made Total Football reality, European Football, BBC, 24 March 2016. http://www.bbc.com/sport/rugby-union/35893027. Accessed 15 Feb 2018
2. Carmichael, F., Thomas, D., Ward, R.: Team performance: the case of English Premiership Football. Manag. Decis. Econ. **21**, 31–45 (2000)
3. Constantinou, A.C., Fenton, N.E., Neil, M.: pi-football: a Bayesian network model for forecasting association football match outcomes. Knowl. Based Syst. **36**, 322–339 (2012)
4. Collet, C.: The possession game? A comparative analysis of ball retention and team success in European and international football, 2007–2010. J. Sports Sci. **31**(2), 123–136 (2013)
5. Hirotsu, N., Wright, M.: An evaluation of characteristics of teams in association football by using a Markov process model. Statistician **52**(4), 591–602 (2003)
6. Higuchi, T., Horino, H., Tsuchiya, J.: Effects of tactical training in university soccer: Using "play centroid". Res. J. Sports Perform. **5**, 176–188 (2013). (in Japanese)
7. Tamura, T., Horino, H., Tsuchiya, J.: Presentation and examination of the classification method about the attack after taking the ball in soccer-Focusing on Fast Break and Possession Play in UEFA EURO 2012. Sport Sci. Res. **12**, 42–55 (2015). (in Japanese)
8. Gama, J., Dias, G., Couceiro, M., Sousa, T, Vaz, V.: Networks metrics and ball possession in professional football. Complexity **21**(S2), 342–354 (2016)
9. Zak, T.A., Huang, C.J., Siegfried, J.J.: Production efficiency: the case of professional basketball. J. Bus. **52**, 379–393 (1979)
10. Berri, D.J.: Who is 'most valuable'? Measuring the player's production of wins in the National Basketball Association. Manag. Decis. Econ. **20**(8), 411–427 (1999)
11. Yanagihara, T., Nakajima, N.: Analysis of turnovers in basketball: focus on attack stage. Juntendo Health Sports Sci. **3**(1), 58–63 (2011). (in Japanese)
12. Kobayashi, K.: An effective game strategy in men's field hockey: from an analysis of the preliminary tournament for the 2008 Beijing Olympic Games. Tokai Gakuin Univ. Bull. Pap. **35**, 33–41 (2009). (in Japanese)

Proposing a Model to Catch the Momentum of Games: Visualization of Momentum in Japanese Professional Baseball

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Abstract. There are some researches about positive streaks (points scored by one team) lead participants to predict the streak's continuation (belief in the hot hand or momentum effect), but negative streaks lead to prediction of its end (gambler's fallacy). In basketball, the validity of "hot-hand fallacy" from successive shoot success was examined [1], and in volleyball, factors that influence momentum on players were explored by using survey data [2]. However, both papers have concluded that the existence of momentum is based on psychological or subjective randomness.

A purpose of this study is to examine within-game momentum in one particular game of Japanese professional baseball quantitatively. We assume that "streaks" in Japanese professional baseball based on superiority or inferiority of the game and the status of play itself which affect the result. Then, we propose a "momentum" model by using the 2015 Japanese professional baseball game data. Lastly, the created model is fitted against the game data of 2016, and the "momentum" of each team, competing against each inning, was calculated and verified. As a result, we could successfully predict a change of streaks of one particular game by the "momentum" model of the game.

Keywords: Baseball · Momentum · Hot-hand · Streak

1 Introduction

Many Japanese professional athletes, reporters and spectators believe in the concept of "flow". Such as "This play has created a "flow" in the team" or "The "flow" has deteriorated due to the head batters of the walk", "flow" is used for many sports scenes. According to Kido [3], "flow" is becoming an indispensable remark in any sports scene.

What is "flow" in sports? Csikszentmihaly [4, 5] developed the flow concept, and operationally defined flow as being a psychological state that can occur when challenges and skills in a situation are both high. Jackson and Csikszentmihalyi [6] defined flow as a person's total absorption into an activity. In Japan, an expression of flow is often used as "form" of a game, "momentum," or "player's condition" and so on.

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Research on “hot-hand” and “streak” are often seen in the area of psychology, which are used as concepts similar to “flow.” “Hot-hand” is a concept that success of success such as basketball shoot makes it easy for additional attempts to succeed [1].

While an existent of “flow” in sports is believed by many sports professionals, there are many negative opinions as well. As for “hot-hand”, a similar in concept to “flow”, some literature regard as a false concept for a long time, saying a famous example of false recognition by human cognitive bias [7, 8].

Bar-Eli et al. [9] review papers about hot-hand over wide varieties of sports; basketball, volleyball, darts, and bowling, in the past 20 years. Among the 24 papers, 11 papers supported hot-hand, and 13 papers did not. Therefore, he concludes that there are more papers that do not support hot-hand than papers that support it.

Therefore, opinions on the existence of “flow,” including hot-hand, in sports are mixed, and their existence is not clearly proven. However, in sports, there are many cases where dramatic scenes are born, which seem that powers beyond the player’s ability and the team’s strength are working. For example, the final game of the 2014 High School Baseball Ishikawa Competition in Japan, Seiryo High School vs. Komatsu Otani High School game, Komatsu Otani took an 8-0 lead into the ninth vs. Seiryo. There is the top of the ninth by Komatsu Seiryo High School was behind by eight points until the ninth inning. Then, they scored nine points in the bottom of the ninth inning, and made a dramatic walk-off win. It is certain that many sports analysts are analyzing “flow” in order to elucidate the dramatic drama factor that happens in sports, and many sports lovers believe “flow” exist.

In this research, we focus on “flow” in baseball games and create a model that can numerically calculate “flow” using actual game data. By visualizing “flow” numerically, we will propose a new way of enjoying professional baseball as people watch at stadiums or on TV.

2 Literature Review

2.1 Hot-Hand and Streaks

Gilovich [1] examined the validity of the existence of “hot-hand” in basketball from games result of field goals and free throw shots. He found that it was not possible to predict the success or failure of the shoot from the state where the shoot was continuous successively (hot state), and it was not possible to prove the existence of “hot-hand” by spiral of successes. And he stated that “hot-hand” is a mistaken belief that an observer overestimates the random result.

Meanwhile, a result of questionnaire showed that basketball fans had tendency to believe players who successively succeeded in shooting tend to succeed more than usual. Therefore, he concluded that the concept of hot-hand is believed by many people [1].

Burns [10] followed the work of Gilovich and verified the relationship between successive shoot success and hot-hand using simulation. He found the relationship between hot-hand and individual shoot continuity was independent (irrelevant). However, collecting the balls to the player whose shoot was continuous, as a team was an effective and an adaptive act as a strategy of the team and stated that the concept of hot-hand was effective.

In baseball, a hitting "streak" is the number of consecutive official games in which a player appears and gets at least one base hit. Albright [11] stated that "There is no doubt that "hot streaks" and "cold streaks" do occur." He conducted research on ability to streak using batting data of the four seasons of Major League Baseball from 1987 to 1990. Although some players showed streakiness in certain seasons, it was expected in a model of randomness and could not find convincing evidence to support streakiness.

2.2 "NAGARE" in Japanese Sports

Research on "NAGARE," *i.e.,* "flow" in Japan has been mainly conducted in volleyball. Kido [12] defined "flow" as a process embodied by the discrimination over the consistency between the prediction of "success succeeds" and its result. In order to grasp the structure of the flow, Kido [12] extracted the discourse on "flow" from interviews with college students who have experience of volleyball. As a result, he concluded that "flow" in volleyball games was composed by concepts such as "invisible negative spiral", "invisible positive spiral", "enforceability of referee", and "timewise grace" which are mutually influential.

Asai and Sagawa [2] examined the factors of "flow" in volleyball by taking questionnaire survey on how the "flow" is relating to the game results, by showing the video of games to experienced volleyball players. Their study found that not only the scores but the overall game situation including the context of the games are influencing "flow." However, this research defined "flow" as "the subjective superiority or inferiority of the game, judged by various factors including the result of the performances, the manager's strategy, etc." This study was done under the premise subjectively.

A research of Yonezawa and Tawara [13] covered "flow" of volleyball, and they stated that "flow" changes due to consecutive points by mistakes.

In this study, we measure how the games' "flow" changes with the relationship between consecutive runs, win and loss, and the relationship between mistakes and outcomes, by using the actual baseball game data. We will show that as the number of consecutive losses increases, the probability of losing the game is higher, consequently the flow changes, and vice versa.

3 Model Construction

In the previous research, the notion of hot-hand and streaks are focused on the performance of each player. On the other hand, the concept of "flow" (NAGARE) in Japan is focusing on what kind of event influences the win or lose of the game.

The definition of "flow" in this research assumes "superiority or inferiority of match formed by game situations and performances related to win or lose," used in Asai and Sagawa [2].

Based on the above assumption, we further assume "NAGARE" would be formed by a combination of "game situation" and "performance result."

In this research, we create a model which numerically calculate "NAGARE based game situation" and "NAGARE based performances" in each inning as follows;

"NAGARE" = ①(Game situation)×②(Performances)

Finally, based on the available at-bat data with variables used to help predict "NAGARE" using that model, we will calculate the value of "NAGARE" for each inning for each team, and make it visualized by a graph to grasp the momentum of the game in Japanese professional baseball in 2015 and 2016.

Parameters of result of at-bat were obtained directly from the database that is made available by Data Stadium Inc., Japan's leading sports information provider.

In this research, we created a "NAGARE" model from 2015 batting data and game data, and applied the model to predict batting results of 2016.

3.1 "NAGARE" Model by Game Situation

Torigoe [14] calculates the winning probability of each inning and each score situation based on Lindsey model [15], using the data of the official records of Japan national professional baseball (NPB) from 2004 to 2008. Lindsey's papers in the 1960's had a great influence on the quantitative analysis of baseball [15]. The first step of his approach was to construct an empirical probability function for the number of runs scored in a half-inning. Following Lindsey's approach, Torigoe [14] used this probability function to model the progression of a game. He modeled the length of the game in each inning, the total runs scored by both teams, and the likelihood that the team would be leading the other by a particular number of runs after a certain number of inning. We apply win probability estimates developed by Torigoe to calculate win probability of each team on 2015 Japanese professional baseball season data. Then, the probability of the home team winning may be defined in the "flow" model by game situation. First, set *pk* as "the probability of getting a batter out in each inning" which may be defined as follows.

$$1 - p_k = \frac{\{Hit + Walk + \ldots + Hit\,By\,Pitch - Double\,Play\}}{At\,bat} \tag{1}$$

Then, the batter out (lose a wicket) probability in each inning are estimated using data acquired from 2015 season, and estimated probabilities are shown in Table 1.

Table 1. Estimated probabilities of lose a wicket for each inning.

Inning	1	2	3	4	5	6	7	8	9
Probability	0.687	0.715	0.698	0.698	0.692	0.676	0.697	0.694	0.709

Next, let's say $\boldsymbol{f_k(y)}$ as probability function of y scores in one inning, and create a probability function of how many points per one inning as follows.

$$\boldsymbol{f_k(y) = \lambda\varphi_1(y) + (1-\lambda)\varphi_2(y)} \tag{2}$$

where

$$\varphi_1(0) = \varphi(0;p_k) + \varphi(1;p_k)$$

$$\varphi_1(\mathrm{y}) = \varphi(0;p_k)\ \text{for}\ \mathrm{y} = 1,2,3,\cdots$$

$$\varphi_2(0) = \varphi(0;p_k) + \varphi(1;p_k) + \varphi(2;p_k)$$

$$\varphi_2(\mathrm{y}) = \varphi(\mathrm{y}+2;p_k)\ \text{for}\ \mathrm{y} = 1,2,3,\cdots$$

The distribution of y follows a negative binomial distribution, and its probability function is defined as follows.

$$\boldsymbol{\varphi(y,p_k) = \binom{y+3-1}{y} p_k^3 (1-p_k)^y} \tag{3}$$

Where it is necessary to have y + 1 people or y + 2 people are on-base in order to score y (y = 1, 2, 3) points in one inning. The ratio of y + 1, y + 2 is set to λ: 1 − λ. In case of 0 points, it is calculated from the probability of 1, 2, 3 (one two three) inning, one runner, and two runners. The value of λ is compared with the relative frequency of scores and a good fitting value is used.

Torigoe (2010) used λ = 0.35, but we adopt λ = 0.4, which is more applicable in this study (Source: The authors created this table based on Torigoe, 2010).

Table 2. Comparison of score probability distribution $\boldsymbol{f(x)}$ and relative frequencies.

Score	0	1	2	3	4	5	>5
Frequency	0.756	0.138	0.060	0.027	0.011	0.005	0.003
$f(y)\ \lambda = 0.4$	0.756	0.131	0.064	0.028	0.012	0.005	0.002
$f(y)\ \lambda = 0.35$	0.766	0.12	0.061	0.027	0.011	0.005	0.002

Let X_k be the score of the kth inning of the first team and Y_k be a random variable representing the score of the kth inning of the second team.

In addition, the function $FT_k(x)$, and $FB_k(x)$ are defined as follows.

- $FT_k(x)$: win probability of the field first team when the top of the y-th inning finished with the x-point-difference.
- $FB_k(x)$: win probability of field first team when the bottom of the y-th inning finished with x-point-difference.

We assume that both teams are the same in quality, and X_k and Y_k (where k = 1, …, 9, 10, 11, 12) are independent. When k $\geq$ 9, $FB_k(x)$ will be

$$FB_k(x) = \begin{cases} 1\,(x \geq 1) \\ 0.5\,(x = 0) \\ 0\,(x \leq -1) \end{cases}$$

First, we evaluate the win probability of the field first team at the end of the top of the 9th inning. If the field first team win the game by more than one point, then the Eq. (4) will be as follows.

$$FT_9(x) = 1(x \geq 1) \tag{4}$$

When the top of the 9th inning ends at x point differences (x $\leq$ 0), the field first team will win, if the team gains −x + 1 point in the bottom of the 9th inning.

When the field first team score −x runs in the top of the 9th inning, the team will go into an extra-inning. The win probability in extra-inning is assumed to be 0.5, and expressed by the following Eq. (5).

$$\begin{aligned} FT_9(x) &= 1 - P(Y_9 \leq -x) + 0.5P(Y_9 = -x) \\ &= 1 - \sum\nolimits_{i=0}^{-x} f_9(i) + 0.5 f_9(-x) \end{aligned} \tag{5}$$

Next, when k $\leq$ 8, the win probability of the field first team in the top of the yth inning is expressed by the Eq. (6).

$$\begin{aligned} FB_k(x) &= \sum_{j=0}^{\infty} P(X_{k+1} = j) FT_{k+1}(x - j) \\ &= \sum\nolimits_{j=0}^{-x} f_{k+1}(j) FT_{k+1}(x - j) \end{aligned} \tag{6}$$

Then, the win probability of the field first team in the bottom of the yth inning will be expressed as

$$\begin{aligned} FT_k(x) &= \sum_{j=0}^{\infty} P(Y_k = j) FB_k(x + j) \\ &= \sum\nolimits_{j=0}^{\infty} f_k(j) FB_k(x + j) \end{aligned} \tag{7}$$

Based on the formulas from (2) to (7), the win probability of each inning and score situation of the field first team are shown in Table 3.

Let assume the win probability of the bat first team is either win or lose, and obtained by subtracting one minus the win probability of the field first team. When the field first team is behind by two points at the end of the top of the 3th inning, the win probability of this team is calculated as 0.2890. At the same time, the win probability of the bat first team is 1 − 0.2890 = 0.7110, respectively.

Table 3. The winning probability of field first team, each score situation.

Ahead/Behind	T1	B1	T2	B2	T3	B3	T4	B4	T5
5	0.9154	0.9436	0.9282	0.9495	0.9336	0.9570	0.9434	0.9653	0.9537
4	0.8556	0.8913	0.8726	0.9007	0.8808	0.9129	0.8951	0.9267	0.9106
3	0.7792	0.8226	0.7988	0.8341	0.8077	0.8495	0.8246	0.8677	0.8437
2	0.6851	0.7347	0.7043	0.7459	0.7110	0.7615	0.7269	0.7809	0.7455
1	0.5752	0.6277	0.5904	0.6354	0.5912	0.6464	0.6007	0.6613	0.6119
Even	0.5444	0.4936	0.5366	0.4929	0.5452	0.4928	0.5491	0.4927	0.5573
−1	0.4248	0.3723	0.4096	0.3646	0.4088	0.3536	0.3993	0.3387	0.3881
−2	0.3149	0.2653	0.2957	0.2541	0.2890	0.2385	0.2731	0.2191	0.2545
−3	0.2208	0.1774	0.2012	0.1659	0.1923	0.1505	0.1754	0.1323	0.1563
−4	0.1444	0.1087	0.1274	0.0993	0.1192	0.0871	0.1049	0.0733	0.0894
−5	0.0846	0.0564	0.0718	0.0505	0.0664	0.0430	0.0566	0.0347	0.0463
Ahead/Behind	B5	T6	B6	T7	B7	T8	B8	T9	B9
5	0.9743	0.9646	0.9844	0.9794	0.9918	0.9891	0.9968	1	
4	0.9427	0.9279	0.9618	0.9532	0.9775	0.9720	0.9910	1	
3	0.8901	0.8661	0.9198	0.9041	0.9474	0.9361	0.9765	1	
2	0.8067	0.7686	0.8451	0.8171	0.8872	0.8643	0.9417	1	
1	0.6833	0.6262	0.7214	0.6744	0.7744	0.7312	0.8642	1	
Even	0.4930	0.5753	0.4953	0.5770	0.4969	0.5978	0.5000	0.6119	0.5000
−1	0.3167	0.3738	0.2786	0.3256	0.2256	0.2688	0.1358	0.1612	0.0000
−2	0.1933	0.2314	0.1549	0.1829	0.1128	0.1357	0.0583	0.0696	0.0000
−3	0.1099	0.1339	0.0802	0.0959	0.0526	0.0639	0.0235	0.0282	0.0000
−4	0.0573	0.0721	0.0382	0.0468	0.0225	0.0280	0.0090	0.0109	0.0000
−5	0.0257	0.0354	0.0156	0.0206	0.0082	0.0109	0.0032	0.0041	0.0000

3.2 “NAGARE” Model by Performances

When watching Japanese baseball games on TV, the commentator frequently uses the word “play to improve flow” or “to make flow worse.”

Also, as for the concept of “hot-hand,” it is often said that there is a “hot” state where play is continuously successful and a “cold” state where play is continuous failure. Therefore, we assume that good or bad performance results will influence the “NAGARE.” We construct the flow (NAGARE) model by performances as Eq. (8).

$$\text{“NAGARE” model due to performances} = \frac{1+[\text{Performance that positively influences}]}{1+[\text{Performance that negatigely influences}]} \quad (8)$$

This model shows that if the performances does not influences the flow, a result for this model will be 1 (one). And if the “performance that positively influences to flow” occurs many times, this result would be larger than 1, and if the “performance that negatively influences on flow” occurs many times, then the result would approach to 0 (zero).

In determining what data to use, we would like to select variables influencing "performance to improve flow" and "performance to worsen flow," and weighted each performance. The independent variables used for each logistic regression analysis are as shown in Table 4.

Table 4. "Performance to improve flow" and "Performance to worsen flow".

	Valuables		Descriptions
Dependent valiable	y1	Win	Takes on the one if the target team lose the game,zero otherwise
	y2	Lose	Takes on the one if the target team win the game,zero otherwise
Performance that positively influences	x1	Single –hit (Offe nse)	Number of single-hit in the games at the time of playing offence
	x2	Long-hit (Offense)	Number of long-hit in the games at the time of playing offence
	x3	Homerun (Offence)	Number of homerun in the games at the time of playing offence
	x3	Walk and Hit By Pitch (Offense)	Number of Walk or Hit by pitch in the games at the time of playing offence
	x4	1 2 3 inning (Defense)	Number of 1 2 3 inning in the games at the time of playing defense
	x5	Runners left in scoring position (Defense)	Number of Runners left in scoring position in the games at the time of playing defense
Performance that negatively influences	z1	1 2 3 inning (Offense)	Number of 1 2 3 inning in the games at the time of playing offence
	z2	Runners left in scoring position (Offense)	Number of Runners left in scoring position in the games at the time of playing offece
	z3	Walk and Hit By Pitch (Defense)	Number of Walk or Hit by pitch in the games at the time of playing defense
	z4	Error (Defense)	Number of error in the games at the time of playing defense

We perform logistic regression analyses to see how much these performances are influencing positively or negatively on winning or on losing. In case of winning the game, a target variable is a dummy variable; "win" is set to "1 (one)," and "0" for otherwise. In case of losing the game, the target variable is set to "1 (one)," and "0" for otherwise. And then, we weight "NAGARE" model by performances from these estimated values.

Results of logistic regression analyses are shown in Table 5 and Table 6.

The "NAGARE" model by performances using these coefficients is shown in Eq. (9). From this model we will make "NAGARE" model by performances of each inning.

Table 5. Result of logistic regression analysis (Performance that positively influences).

	β	P-value
Single-hit	0.094	0.001
Long-hit	0.247	0
Homerun	0.624	0
Walk and Hit By Pitch	0.101	0.007
1 2 3 inning	0.518	1
Runners left in scoring position	0.398	0

Table 6. Result of logistic regression analysis (Performance that negatively influences).

	β	P-value
1 2 3 inning	0.563	0
Runners left in scoring position	0.404	0
Walk and Hit By Pitch	0.279	0
Error	0.348	0.002

First, we count the number of occurrences of performances related to the "NAGARE" of each team at the end of each inning. Then, in formula (9) of x_n, we substitute the corresponding β from Table 5, and for z_n, we substitute the corresponding β from Table 6, and this result will consider the "NAGARE" model by performance.

When we calculate "NAGARE," we use the data of both at-bat and on-base of the same team. For on-base, we used the data of the previous inning. For example, if a team is a visitor, at the top of 4th inning, we use 4^{th} inning on-bat data, as well as the on-base data in the bottom of 3th inning for the "NAGARE" model for this team.

$$\text{“NAGARE” due to performances} = \frac{1 + 0.094 \times x_1 + 0.247 \times x_2 + 0.624 \times x_3 + 0.101 \times x_4 + 0.518 \times x_4 + 0.398 \times x_5}{1 + 0.563 \times z_1 + 0.404 \times z_2 + 0.279 \times z_3 + 0.348 \times z_3} \quad (9)$$

4 Test of "NAGARE" Model

4.1 Test of "NAGARE" Model Part 1

Figure 1 shows the ratio of "NAGARE" for each inning calculated by the "NAGARE" model in ORIX Buffaloes (Buffaloes) vs. Hiroshima Toyo Carp (Carp) game on June 1, 2016, from a perspective of Carp. A black solid line in Fig. 1 shows the score differences between two teams.

In this game, Buffaloes scored the first run in the first inning, and "NAGARE" is leaning toward Buffaloes side. Since Buffaloes scored additional points in the next inning, "NAGARE" score is further inclined to Buffaloes. After that, both teams have no points, the ratio of "NAGARE" has not changed much until the 5th inning. When

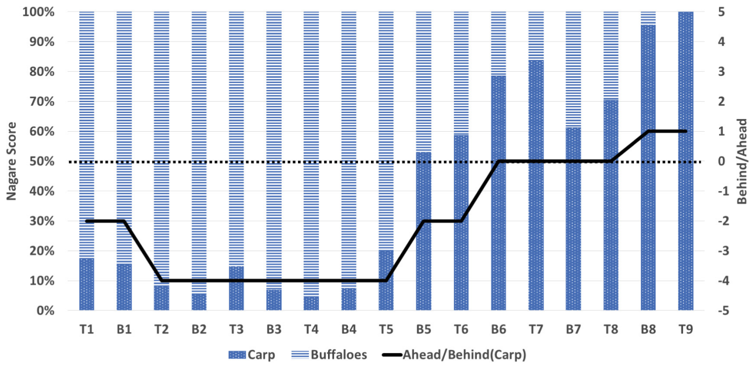

Fig. 1. Result of "NAGARE" model at the game between Buffaloes and Carp.

Buffaloes' attack finished in the top of the 5th inning, Carp scored in the next inning as soon as the ratio of "NAGARE" is slightly leaning toward Carp, and Carp scored two points.

Although the Carp is losing in the top of the 6th inning finished, the value of "NAGARE" shows the same proportion for both teams.

In the 7th inning, Carp scored, and equalized with Buffaloes; the ratio of "NAGARE" had largely lean toward Carp. Finally, the end result was a come-from-behind win for Carp.

4.2 Test of "NAGARE" Model Part 2

Figure 2 shows the ratio of "NAGARE" for each inning calculated by the "NAGARE" model in Hanshin Tigers (Tigers) vs. Chunichi Dragons (Dragons) game on August 31, 2016, from a perspective of Dragons. A black solid line in Fig. 2 shows the score differences between two teams.

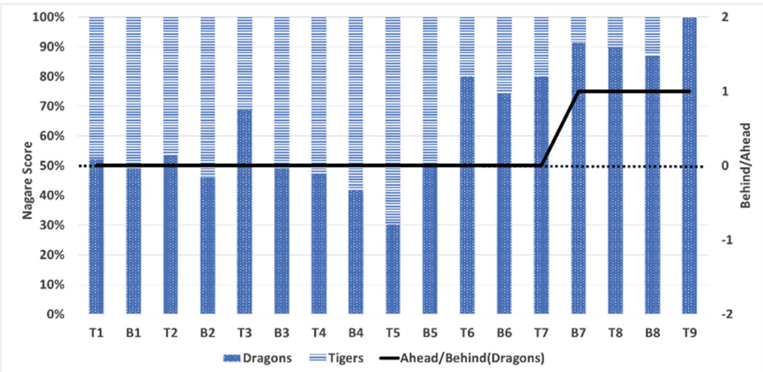

Fig. 2. Result of "NAGARE" model at the game between Dragons and Tigers.

Both teams did not scored until 7th inning in this game, but we can see that the score of "NAGARE" of the game is changing. In the first half of the game, "NAGARE" score of both teams are about the same. "NAGARE" is inclined to the Dragons side in the 3th inning, but it is inclining to the Hanshin side in the 4th to 5th inning. "NAGARE" is inclined to the Dragons side in the 5th to 6th inning, Dragons was the first to score, and they won the game. Since this game had no points on both teams until the second half, we could not judge from the game scores which team had momentum.

However, by using the "NAGARE" model which calculated from the combination of the score condition and the success status of play, it was possible to see the change of the game situation in each inning.

4.3 Test of "NAGARE" Model Part3

Figure 3 shows the ratio of "NAGARE" for each inning calculated by the "NAGARE" model in Yomiuri Giants (Giants) vs. Hiroshima Toyo Carp (Hiroshima) game on August 7, 2016, from a perspective of Carp. A black solid line in Fig. 3 shows the score differences between two teams.

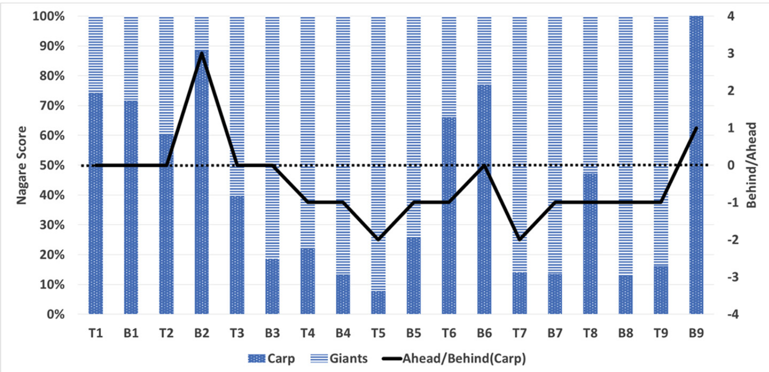

Fig. 3. Result of "NAGARE" model at the game between Giants and Carp.

The change in the ratio of "NAGARE" was intensifying, as the scores changed greatly in this game.

Immediately after "NAGARE" score lean to the Carp side in the top of the 1st inning, Carp scored the first point in the next inning. However, in the 3rd inning, the Giants tied the game right away, and scored additional points in the fourth and fifth inning. Along with that, "NAGARE" also was leaning to the Giants side at once.

After that, Carp scored one point in the 5th inning, "NAGARE" also changed to Carp side, tying in the 6th inning. Then, Giants was reversed in the next inning. However, Carp scored another points in the 7th inning. At the end, Carp won the game because of scored additional 2 points in the 9th inning.

It was a seesaw game, and hard to say which team would win. By using "NAGARE" model, we may be able to say that the flow (NAGARE) of this game changed very intensely.

5 Conclusion and Future Study

In this research, we focused on "NAGARE" that is believed to exist among sports enthusiasts in Japan. We defined "NAGARE" of baseball as "superiority or inferiority of match formed by game situations and performances related to win or lose."

Then, we created the "NAGARE" model from the win probability, according to the game situation and the influence rate on the win/loss of each action obtained by the logistic regression analysis using the data of 2015 season.

Finally, we tested the "NAGARE" model with three games of 2016 season. Using the "NAGARE" model, we found that some games' score was changed after the ratio of "NAGARE" model changed. Moreover, some games showed that a level of "NAGARE" model was changing, even if the score situation did not change. From these results, we were able to express something like "momentum" or "flow" of the baseball games using the "NAGARE" model.

However, when the score situation changed drastically, "NAGARE" changed dramatically as well, and it was difficult to feel the "flow" from "NAGARE" model.

Therefore, it is need to extend the "NAGARE" model, using more detailed data such as each out count or each strike count.

In this research, we chose the performance variables subjectively which influence the" NAGARE". The further studies are needed in order to search "under what kind of circumstances, what performances changes the flow in the game" from questionnaire survey to baseball players and/or sports enthusiasts about. Incorporating survey data into the current model, we may be able to create a new model that can sense "flow" with different point of view.

By improving the "NAGARE" model of the game created in this research, we would like to implement it into the new way of watching the professional baseball at the stadium or data broadcasting. We may be able to provide a new way of enjoy baseball game by watching how the "NAGARE" of each team moves. It will be also covered in our future study.

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References

1. Gilovich, T.: The hot hand in basketball: on the misperception of random sequences. Cogn. Psychol. **17**(3), 295–314 (1985)
2. Asai, Y., Sagawa, M.: Process of "streaks" in the volleyball game and game situation (in Japanese). Coaching Stud. **27**(1), 9–22 (2013)

3. Kido, T.: The sociological study about the intentional creation of "NAGARE" in volleyball game -the case study of former Japanese national volleyball player (in Japanese). Kato Yoichi, Volleyball Res. **16**(1) (2014)
4. Csikszentmihalyi, M.: Beyond Boredom and Anxiety. Jossey Bass, San Francisco (1975)
5. Csikszentmihalyi, M.: Flow: The Psychology of Optimal Experience. Harper & Row, New York (1990)
6. Jackson, S.A., Csikszentmihalyi, M.: Flow in Sports: The Keys to Optimal Experiences and Performances. Human Kinetics, Champaign (1999)
7. Nodera, A.: Beliefs regarding continued success or failure (in Japanese). J. Facul. Hum. Cultures Sci. Fukuyama Univ. **15**, 27–34 (2015)
8. Abe, K.: Miscognition of random sequences in sports scene: penalty kicks as a clue (in Japanese). J. Facul. Hum. Cultures Sci. Gakushuin Univ. **24**, 135–159 (2015)
9. Bar-Eli, M., Avugos, S., Raab, M.: Twenty years of "hot hand" research: review and critique. Psychol. Sport Exerc. **7**, 525–553 (2006)
10. Burns, B.D.: The hot hand in basketball: fallacy or adaptive thinking? In: Proceedings of the Twenty-third Annual Conference of the Cognitive Science Society, pp. 152–157 (2001)
11. Albright, S.C.: A statistical analysis of hitting streaks in baseball. J. Am. Stat. Assoc. **88** (424), 1175–1183 (1993)
12. Kido, T.: The sociological study about "NAGARE" in volleyball game − based on the qualitative analysis about conversation data of college players (in Japanese). Volleyball Res. **14**(1), 28–35 (2012)
13. Yonezawa, T., Tawara, N.: A study on "the game flow" of the volleyball: on the relation between the continuous lost-point and victory or defeat (in Japanese). Sports Health Sci. Res. **41**, 1–7 (2010)
14. Torigoe, N.: Win probability added in sabermetrics (statistical experiment and its related topics) (in Japanese). Res. Inst. Math. Sci. Kôkyûroku **1703**, 1–9 (2010)
15. Lindsey, G.R.: The progress of the score during a baseball game. J. Am. Stat. Assoc. **56**, 703–728 (1961)

The Present and Future of Macroergonomic Systems

The Future of Macroergonomic Manufacturing Systems

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Abstract. The goal of the paper is to present research results concerning the future of Macroergonomic Manufacturing Systems (MMS). This research were based on an expert version of Delphi method and fuzzy set applications. Modern Macroergonomic Manufacturing Systems are based on industrial work model which started at the end of nineteenth century. In this model enterprises work on the principles of tasks repeatability and their perfectionism. The workers in a frame of Macroergonomic Manufacturing System, they are still doing the same with the highest efficiency and productivity. The development of automation and robotics based on the rules of Artificial Intelligence will lead to a change in this classic model in the future. The future of Macroergonomic Manufacturing Systems is associated with a positive cooperation scenario of human natural intelligence with the "machining" Artificial Intelligence. In the model of the future, the enterprises will have to swear that the purpose of Macroergonomic Manufacturing Systems functioning is lasting and development. Current profit as a means of achieving this purpose will be replaced by the desire to have the best, professional and creative staff, empowered as well as identifying with the enterprise's goals.

Keywords: Macroergonomic Manufacturing Systems · Delphi method
Fuzzy sets

1 Introduction

In the dichotomous division of the contemporary knowledge on Science and Technology, ergonomics could be placed in the second mentioned area, because we call it Ergonomics or Human Factors Engineering or Human Factors in Engineering. Ergonomics works not on knowledge acquisition about what is, but rather on forming engineering solutions, that does not exist yet.

It is obvious that Aristotelian dichotomists (Science vs. Technology) are some sort of classified simplification of the real world dominated by fuzziness. Hence, Science and Technology often operate on the same field. Science enters into creative processes of practical implementation of own discoveries and evolves in a fuzzy way into the sphere of Technology. The same happens in the opposite direction: the process of

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technological, organizational and constructional progress allows Technology discovering (cognition) new phenomena, for which it solves appearing problems and, in the same time, feeds the sphere of Science [12, 13].

Such situation can be observed for year on the ground of the modern ergonomics, which, as a field of knowledge with a contextual character, constitutes an almost demonstrative example of the clash of "enchantments of the pure science" and "temptations of the obtuse utilitarianism". The character of scientific research in the area of ergonomics does not characterize with typical features of Science; cognitive processes have usually a quasi-empirical character. Cognitive research within ergonomics focus on creating methods for solving problems that result from the phenomena that is already well known but too complicated to find an accurate scientific solution of issues related to it. Today's ergonomics focuses mainly on solving problems, using both knowledge and experience and intuition. Ergonomics must be often featured by a technological pragmatism, which results from the necessity of finding solutions before science fully explains some phenomena [13, 6]. The purpose of the article is to elaborate a procedure for ranking macro-ergonomic system maturity level in the area of sustainable development.

2 Modern Macroergonomic Structures

In the seventies of the twenties century, Pacholski made an attempt of universal defining the subject of the research and ergonomic applications. He has determined this subject as a relation (system, network, hybrid) combining: human societies (mission, strategy, objectives & tasks of the MMS; identity of the MMM, qualifications & skills, interpersonal relations) and the organizational and technological component (organizational structure of the MMS, functions of organizational units, procedures, scopes of activities, instructions; equipment assets of the MMS, technology). In his works from the mentioned period and further (which concerned ergonomics of industrial manufacturing processes), the author consequently named this relation a Multiagent Manufacturing System [10, 11]. This approach has a universal character because in both encloses: Man–Machine Unit or Man-Machine Interface Technology Systems (reduced to the unitary form) and Overall Organization-Machines Technology [5, 1]. In eighties of the twenties century Hendrick called these interfaces: Macreoergonomic Systems (from the third-generation ergonomics).

If to treat historically the problem of the subject of research and ergonomic applications, then, according to the universal proposal presented before, one could say about four stages of the evolution of this interface (MMS). The first stage would refer to pre-industrial societies and the technological and organizational component in form of methods and tools for hunting or simple agricultural techniques and tools. The second stage encloses industrial societies, which have machines, energy and electronics on their disposure. The modern, third stage, information societies use computer networks and new media. The further, fourth stage might refer to creative and empathic societies and to the technological and organizational component in form of nanotechnology applications and of artificial intelligence.

Current technological-organizational "partners" of human communities (Macroergonomic Manufacturing Systems) can be also identified more precisely on the basis of the concept of economic cycles. These "partners" usually have the form of following so-called "fundamental innovations" (the steam machine and railways, the electricity and the internal-combustion engine, aviation, energetics and electronics, computer networks, pro-ecologic solutions, artificial intelligence and nanotechnology). These innovations, constituting the technological and organizational reaction to the evolution (into the humanocentric direction) of "social imperatives and needs" (like improving the efficiency of work and trade, the availability and mobility of assets, increase if the standard of life, energy networks, travelling, ecology, knowledge networks, psychological and social fitness, human health and quality of life). Today's Macroergonomic Manufacturing Systems (linking human societies and the technological and organizational component) concern the internal organization of enterprise, but they can also enclose structural conglomerations of groups of many enterprises. These systems, represented by modern corporations, have an ordered functional form, but they also can be network complex interrelation, hybrid or chaotic connections. The macroergonomic interpretation of the functioning of such MMS focuses on the particular role of their "essence", which is a composition of human communities with their technological innovation and innovative managerial solutions, social and business objectives [8].

The modern period of transition into the fifth or even sixth Kondratief's economic cycle is characterized with a radical change of contemporary "human component": cohesive, structurally complete and ordered, which constitutes the subject of ergonomics. The evolution of human societies' behaviour within MMS connected with the macroergonomic system developing and lasting evolves three stages [13]:

- MMS's management must constantly control the staff (people are lazy by nature),
- MMS's management must provide necessary help and support to the staff (people are able to work hard if they are supported and if they have help in the realization of their tasks,
- MMS requires maintaining a consensus between the management and the staff and granting possibility of participation for every individual person within the MMS (people like to achieve satisfaction from their sense of competences, self-reliance and self-control of own achievements, as well as from the freedom of choice).

Democracy and market freedom have caused that societies where fascinated by the concept of the network, but next they started protesting the functional, structured order. Today, democracy and market are ruled by the research of the "buyer". Societies leave traditional hierarchies and authorities in favor of a so-called „guru", who does not have to convince us, he only needs to be popular. There is chaos appearing within the human factor of ergonomics. The contemporary, "pro-society" order of the organization is being replaced by a formation called a "swarm". Modern ergonomics methodology has been forced to transfer observations from the world of life beings (evolution algorithms and neuronal networks, behaviorism taken from bees, ants or other swarms) to the ground of ergonomic methodology of research and applications, in order to find the key for lasting and to the development of such syncretic solution of own multiagent MMS [9].

3 The Changes of Manufacturing Paradigm

The concept of paradigm by Thomas Kuhn (that is: sets of notions and theories creating attitudes of the determined field of study) assumes the constancy of the adopted way of perceiving reality (model) so long until it is permanent empirically and implemental. However, it isn't possible to rank the ergonomics among the group of permanent-paradigmatic disciplines. Macroegonomic Manufacturing Systems are acting in the conditions of the surprising and growing turbulence and unpredictability of environment changes, in different dimensions of this changeability: technological, economic, social and political (Fig. 1). The synthesis describing the turbulence and the changeability of contemporary MMS surroundings (macroenvironment and competitors) includes following facts:

– changes in the MMS environment are more and more often without continuation, where the previous experiences become less and less useful (a degree of novelty of changes grows),
– MMS are being forced to devote more and more large own resources for maintaining marketing and innovative connections with their environment,
– the intensity of shortening time of launching organizational and technological innovation is growing,
– the line between environment and MMS is faded,
– an interactive and synergetic influence of diverse external factors on manufacturing MMS is growing.

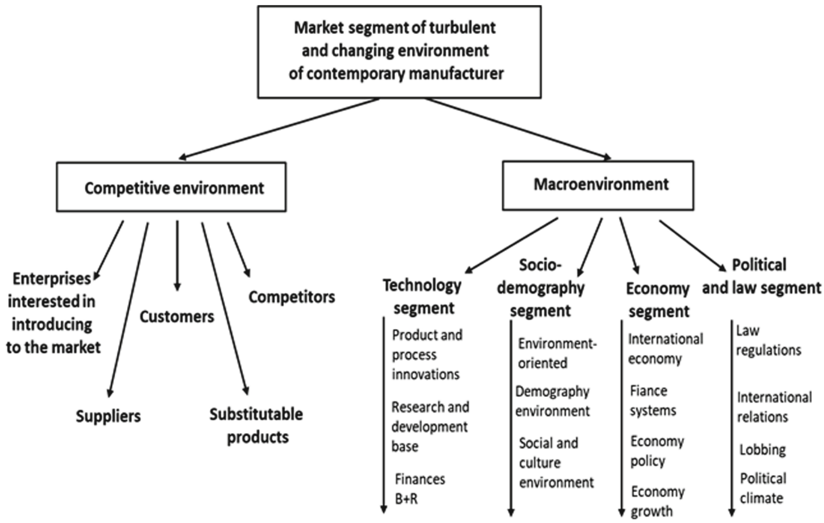

Fig. 1. The dimensions diversity of the turbulence and unpredictability of MMS environment changes

4 Research

The examinations concerning the future of Macroergonomic Manufacturing Systems (MMS) were carried on the example of the sector of the public transport vehicles. Three large enterprises producing buses, minibuses, trams and metropolitan local coaches were provided with analysis. As a schemat it is possible to divide manufacturing processes of these vehicles in three following phases: the subprocess of the structure of the body-work construct of public transport vehicle, the subprocess of varnishing and rust-proof as well as assembly technologies of the complete vehicle [7]. Showing the prospective changes of the relation linking social communities and the technological-organizational component within MMS were a purpose of research. The change of these relations would mean the changeability of present-day paradigms of manufacturing of mentioned above transport vehicles in practice. Expert opinions concerning perspective changes of paradigms of the technology and the organization of machines manufacturing were collect with method being based on Delphi approach. For finding measures hierarchizing linguistic opinions of experts, a theory of fuzzy sets was used. In the role of experts, the sixteen specialists were exploited. Twelve of them are managers of representing mentioned manufacturing enterprises. The experts were also university scientists specializing in the following disciplines: transport (manufacturing and exploitation), the organization and management of machines manufacturing processes and ergonomic engineering. As a part of the expert panel discussion using brainstorming method, the six following paradigms of the future MMS reconfiguration were determined:

– the repetitiveness of tasks and their perfectionism as well as productivity improving of manufacturing processes of transport machines,
– the stock and process flexibility vs. changeability of the conditions of running a machine manufacturing business,
– industrial and humanoid robots in the organization of transport machines manufacturing processes,
– radical shortening of life cycle of technological and organizational innovations as well as implementation of the artificial intelligence methods in the development of lean and agile manufacturing of the public transport vehicles,
– the turbulent and unpredictable changeability of the conditions of running a machine manufacturing business vs. dynamic character of irregular changes of the technology and the organization of transport machines manufacturing,
– the maximizing of the business profit vs. intelligent organizing of public transport vehicles manufacturing processes.

Put the questions for the sixteen mentioned experts were enunciated as is presented on the example below consist of four questions (2, 3, 5 and 8), selected out of the full set consisted of ten questions:

Questions no 2:

In what way, in the scale from 1 to 5 (in the perspective of fifteen nearest years), turbulent and unpredictable changeability of conditions of running a machine manufacturing business, will move from the balanced model of continuation of the technology and the organization changes of manufacturing processes to the model of the dynamic sharp changes?

Questions no 3:

In what way, in the scale from 1 to 5 (in the perspective of fifteen nearest years), the growing intensity of time shortening of the innovation concerning the organization of machines mass-production for its commercialization, will cause the need for considering artificial intelligence methods in the product development process and manufacturing processes of the public transport vehicles?

Questions no 5:

In what way, in the scale from 1 to 5 (in the perspective of fifteen nearest years), the assortment flexibility selected, based on universal equipment (technological and organizational) of mass-production processes of the public transport vehicles will enable surviving and the development of the enterprise manufacturing these vehicles?

Questions no 8:

In what way, in the scale from 1 to 5 (in the perspective of fifteen nearest years), an implementation of humanoid robots will be possible in the organization of the mass-production processes of the public transport vehicles?

The complete set of ten questions, on the basis of the Delphi method, was introduced to sixteen experts. For the numerical results received in the first round next a graph of their layout was drafted, a median was appointed as well as an interquartile (K1, K3) range was determined. K1 range was such a variable value which divided obtained results in two parts, this way that, in one a 25% of the reply was found with the variable smaller than K1, in second 75% with the variable larger than K1. However, the third K3 quartile contained the 75% of the reply in the first part with the variable smaller than K3, in second 25% of the reply with the variable larger than K3. Within the set of ten questions, experts gave their opinion (for needs of the second round) enumerated in a frame of the first round: median, interquartile range and one's individual response from this round. Taking into consideration such a set of information, the experts for the second time made the answer to questions from the first round. If their previous answer lay apart from the interquartile range and the new reply was also outside this range, the written argumentation was required. In this way they were forcing into passing experts of undecided and not-having appropriate arguments, to the majority comprising group, that is for which replies are located in a range (K1, K3). Examples of charts of four-round process of experts' coming to an agreement (in frames of questions: 1 and 3) is showed on Fig. 2.

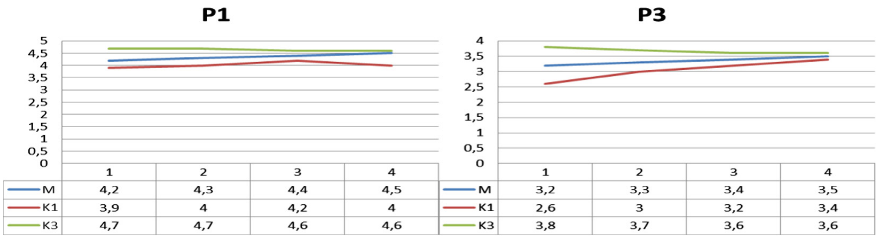

Fig. 2. Examples of charts of four-round process of experts' coming to an agreement

Suggested, five-degree of linguistic scale, for the needs of experts evaluation concerning actuality degree of each of ten paradigms is the following:

– low degree of the paradigm actuality,
– medium degree of the paradigm actuality,
– significant degree of the paradigm actuality,
– high degree of the paradigm actuality,
– very high degree of the paradigm actuality.

Next, a linguistic variable Z was implemented which is describing the paradigm actuality degree. The recommended fuzzy scale for this variable is described as follows [2, 3]:

– low actuality: $0 < z < 0{,}333$;
– medium actuality: $0{,}167 \leq z < 0{,}5$;
– significant actuality: $0{,}333 \leq z < 0{,}667$;
– high actuality: $0{,}5 \leq z < 0{,}833$;
– very high actuality: $0{,}667 \leq z \leq 1$

Let us introduce dj the result of an assessment by an expert j (dj ∈ 1, 2, 3, 4, 5). According to the fuzzy set theory, membership for set N can be expressed through μN(x) - membership function with an interval [0,1]. For every evaluation of expert result dj, fuzzy sets were assigned: Ns, where: s = 1, 2, 3, 4, 5 (according to the choice of experts). The following layout of the scale of the paradigm actuality degree was accepted:

– (0, 0,333) - low actuality degree,
– (0,333, 0,667) - medium and significant actuality degree,
– (0,667, 1,0) - high actuality degree.

Next, the standardized fuzzy set, as a model of membership function for fuzzy sets was used [2–4].

Next, the f_{sf} as an element of a fuzzy set s and m_{sf} as a membership function for the corresponding fuzzy set element was introduced. The probability of expert assessment was count in the following way:

Counting Pi: Intermediate assessment of probability, i = 1, 2, 3., reflecting a frequency of choice done by an expert:

$$P_1 = \sum_{f=1}^{3} f_{1f} m_{1f};\ P_2 = \sum_{f=3}^{5} f_{2f} m_{2f};P_3 = \sum_{f=5}^{7} f_{3f} m_{3f}.$$

Counting Pi: Probabilities of low, medium and high actuality paradigm degree in the future, where i = 1, 2, 3.

To count probabilities, it was required to normalise the intermediate assessment of probabilities according to following formula:

$$\mathrm{p}_i = P_i / \sum_{\mathrm{i}=1}^{3} P_i.$$

5 Research Results and Conclusions

The highest experts assessments (high and very high paradigm actuality degree) were achieved for four following and future (in a perspective of a year 2033) MMS issues:

- Productivity improving of processes of mass-production of public transport vehicles in a frame of MMS will be based on the paradigm of the task repetitiveness of objectives and on their perfectionism.
- The turbulent and unpredictable changeability of conditions of running a machine manufacturing business concerning public transport vehicles in a frame of MMS will move these conditions from the current continuation model of technology transformations and organization of production to the model of dynamic sharp changes.
- Process flexibility of the organization of mass-production of the public transport vehicles in a frame of MMS, depending on simple and fast rearming and changes programs of devices responsible for the production, will support recognizing by the enterprise the changeability and the turbulence of the environment (competitive, technological, social-demographic, political-legal and economic), as the favourable circumstance rather than opposing for MMS goals.
- Programmable, multitask industrial robots will improve the productivity of processes of mass-production of the public transport vehicles in a frame of MMS.

Numerical values of two first mentioned above paradigms of perspective lasting and development of MMS exceed 0.800 by the assumed threshold 0.667. In the center of expert evaluations of the MMS future paradigms actuality concerning manufacturing of public transport vehicles (range: 0.333, 0.667), the four following condition (medium and significant) were developed:

- The growing intensity of shortening time of the innovation development concerning technology and the organization of mass-production of the public transport vehicles and its commercialization will cause the use of artificial intelligence methods in the new product development process and carrying out processes of lean and agile manufacturing in a frame of MMS.
- Both methods of the artificial intelligence based on the symbolic knowledge representation as well as methods of the artificial intelligence based on intuitive simulation of the nature processes with managing these resources will be possible to use in organization of the mass-production processes of the public transport vehicles in a frame of MMS.
- An implementation of humanoid robots will be possible in the organization of processes of mass-production of the public transport vehicles.

– The profit maximization as the factor enabling lasting and the MMS development of the mass-producing of public transport vehicles will be replaced by intelligent organizing of manufacturing processes, based on self-improvement, professionalism, creativity, empathy and community of activities.

The low degree of the future actuality (below 0.333) got the paradigm formulated as follows:

– The assortment flexibility based on universal technological and organizational equipment of mass-production of the public transport vehicles in the frame of MMS, in the low degree will enable lasting and the development of the manufacturing company.

One should emphasize that the nine-elements experts' opinion included in conclusions which results from the fact of connecting into one future paradigm of some issues of implementing two different methods of artificial intelligence. At the beginning, this paradigm has been divided into two separated questions, finally result gave very coincident results.

References

1. Jasiulewicz-Kaczmarek, M., Saniuk, A., Nowicki, T.: The maintenance management in the macro-ergonomics context. In: Goossens, R.H.M. (ed.) Advances in Social & Occupational Ergonomics Proceedings of the AHFE2016 Conference on Social & Occupational Ergonomics, vol. 487, Advances in Intelligent Systems and Computing, pp. 35–46, 27–31 July, Walt Disney World®, Florida, USA (2016). https://doi.org/10.1007/978-3-319-41688-5
2. Kalkowska, J., Kozlov, A.V.: Decision making process for the knowledge-based enterprise: fuzzy sets theory application to the strategic management. In: Borzemski, L., Grzech, A., Świątek, J., Wilimowska, Z. (eds.) Proceedings of the International Conference Information Systems Architecture and Technology 2015 (ISAT 2015), Part III: Advances in Intelligent Systems and Computing Series, pp. 135–146. Springer (2015)
3. Kalkowska, J., Pacholski, L.: Simulation Technologies on Agile Reconfiguration of Assembly Production Process, Przegląd Organizacji, nr 2/2017, pp. 49–56, Wydawnictwo Naukowe Organizacji i Kierownictwa, Warszawa (2017)
4. Kałkowska, J.: Information and communication technologies supporting fuzzy knowledge management. In: Schlick, C.h., Trzcieliński, S. (eds.) Advances in Ergonomics of Manufacturing: Managing the Enterprise of the Future, Proceedings of the AHFE 2016 International Conference on Human Aspects of Advanced Manufacturing, pp. 363–374, 27–31 July 2016, Walt Disney World®, Florida, USA. Springer International Publishing (2016)
5. Pacholski, L., Jasiak, A.: Macroergonomic effects of rapid economic renewal. In: Scott, P.A., Bridger, R.S., Charteris, J. (eds.) Global Ergonomics, pp. 855–858. Elsevier, Amsterdam, Oxford, New York (1998)
6. Pacholski, L., Mateja, B.: Macroergonomic development of industrial production processes. In: Salvendy, G. (ed.) Advances in Occupational, Social and Organizational Ergonomics, Advances in Human Factor and Ergonomics Series, pp. 802–812. CRC Press/ Taylor and Francis Group, Boca Raton, London, New York (2010)

7. Pacholski, L., Pawlewski, P.: The usage of simulation technology for macroergonomic industrial system improvement. In: Goossens, R.H.M. (ed.) Advances in Social & Occupational Ergonomics, Advances in Intelligent Systems and Computing, vol. 487, pp. 3–14. Springer International Publishing (2017)
8. Pacholski, L., Piotrowski, K.: Political ergonomics, macroergonomic battles. Hum. Fact. Ergon. Manufact. **18**(5), 515–524 (2008)
9. Pacholski, L., Trzcieliński, S., Wyrwicka, M.: Clustered macroergonomic structures. Hum. Fact. Ergon. Manufact. Serv. Ind. **21**(2), 147–155 (2011)
10. Pacholski, L.: An application of fuzzy methods in the complex ergonomics diagnostics of industrial production systems. In: Karwowski, W., Mittal, A. (eds.) Applications of Fuzzy Set Theory in Human Factors, pp. 211–225 (1986)
11. Pacholski, L.: Ergonomic issues of the neural integrated human- computer interaction. Int. J. Cybern. Syst. **37**, 219–228 (2006)
12. Pacholski, L.: Human factors and well-balanced improvement of engineering. In: Vink, P., Salvendy, G. (eds.) Advances in Social and Organizational Factors, Human Factors and Ergonomics Series, Chap. 31, pp. 288–297. CRC Press/ Taylor and Francis Group (2012)
13. Pacholski, L.: Macroergonomic premises for organizational innovations in business corporations. In: Ahram, T., Karwowski, W., Marek, T. (eds.) Proceedings of the 5th International Conference on Applied Human Factors and Ergonomics AHFE 2014, pp. 3741–3747 (2014)

Improvement Method of Subcontract Phase of Production Process in IT Production Management System – Case Study

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Abstract. A subject of the paper is a model of production process in IT production management system, presented in simplified form of items flow diagram through technological operations and stores between operations.

Observational research as well as data error reports created for administrator of IT production management system, were carried out under real conditions of company of producing machine parts. This research provided with the knowledge about quality of information given to the IT system users involved in planning process, manufacturing control and production management.

The aim of the paper is to improve a subcontracting phase of the analyzed model of the production process in IT system and its graphical presentation in the form of items flow diagram.

The presented diagram illustrates improved flow of items through technological operations and stores between operations in the production process, improving in this way planning process, manufacturing control and production management by providing better quality information.

Keywords: Organizational method · Scientific research methodology
Organizational problems solving · Subcontracting phase · Improvement method
Production process model

1 Introduction

Based on historical data, a statement can be made, that from the beginning of their existence, human beings had an ability to organize and manage their activities. It was closely related to the intentional use of the tools necessary to perform day-to-day activities. Awareness of a possibility to manage operations more efficiently and a need to use better tools, has contributed to the development of innovation in the area of organization and management.

Organizational activities, carried out in a spontaneous manner, depending on the innate abilities of leaders were not a part of any methodological framework. The origins of a scientific approach can be found among ancient thinkers who proclaimed the principles of efficient operation, which is a generalization of a practical experience in various fields of activity: economic, administrative, military, exploratory.

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2 Main Directions and Theories of Improving Organization

Making a review the main directions and theories of organization and management, one can say that the classic approach at the problems of the organization included two main directions: scientific management, focused on the organization's employees and on ways of improving their productivity, and administrative management, focused on the organization and on the ways of making it more effective and efficient [2–7, 15, 16, 18].

Most of theoreticians of the classical view focused on controlling and standardizing the behavior of these units. On the contrary, the behavioral approach focused on individual attitudes and behaviors and on group processes. Behavioral perspective has provided important conclusions from the field of motivation, job satisfaction, stress, leadership, group dynamics, organizational policy, human conflicts and organizational structure [2–7, 15, 16, 18].

During World War II, special teams were formed, whose task was to support an army to use war resources more efficiently and more effectively. This approach uses the quantitative methods in management, hence the name quantitative perspective.

Quantitative perspective can be divided into two directions: quantitative management theory and operational management [3, 16].

Quantitative management theory focuses on the development of mathematical models which represent a simplified model of the system, process or relationship. Mathematical models of quantitative management theory often provide support for decision making processes and solving management problems.

Operational management is used to assist organization in effective production of products and services.

Approaches to management: classical, behavioral and quantitative, although each of them has different assumptions and often may give different results, can still complement one another. A proper understanding of management requires sometimes an approach which integrates all other approaches. Such perspective can be divided into systemic and situational [3, 16].

Systemic perspective assumes treating organization as a whole, that is an mutually connected sets of functioning units.

The second type of approach to management – situational – suggests that universal theories such as classical, behavioral and quantitative approach, are not applicable, because every organization is different, and decision making and behavior of the Management are conditioned by unique elements, characteristic only for a given organization.

3 Organizational Method

Colloquially the method is referred to a way of proceeding, intentionally, consistently and systematically used; a set of activities and resources used to achieve a goal; a way of performing a task, solving a problem; a set of general assumptions accepted in specific research. Mikołajczyk [14] defines this term as "a rational and systematic proceeding, which is used to do or to say something".

An interesting concept of a method is presented by Martyniak [10], who says that "a method cannot be too sharply drawn, because excessive precision annihilates it. A method should determine the way it behooves us to follow and it should pave several possible routes, maximizing the chances of success in problem solving with the current state of knowledge".

Lis [8] explains these concepts with the following words "by a method we mean a procedure used to achieve a particular purpose, a conscious and repeatable manner, systematically applied in all cases of a given type. (…) A technique, in this case, means defining tangible resources, such as tools, equipment, patterns, diagrams, etc. applicable in a given type of work. These tools may include here all kinds of forms, diagrams, physical models, mathematical models or specialized equipment, etc.".

Martyniak [9] analyzing a method at different levels of generalization, indicated the correlation between method and technique, saying that at the highest level, a method is close to a general rule, such as the one resulting from an organizational cycle of Le Chatelier. At a lower level, there are methods of modeling, and at the lowest, the routine ways – patterns of action, which can be represented by strict schemes that is techniques [11, 13].

In many cases can be found a term "scientific method", meaning such which "is used regularly, often in investigation of different problems, using results of research to create theoretical generalizations or empirical verification of set hypotheses" [10].

A scientific method is therefore a general scheme of research proceedings, which should include more specific (detailed) patterns, that is techniques of proceeding with regard to the analyzed reality.

"Organizational method is a systematized proceeding, based on scientific principles of research, which is intended to solve problems" [10]. Achieving this goal is facilitated by the use of organizational techniques, by which it should be understood the specific patterns of conduct. They consist of two basic elements:

- research instrument in form of a graphical model, physical model, mathematical model and specialized equipment,
- manner of using this instrument to complete the assumptions of the method.

4 Sources of Contemporary Scientific Research Methodology

The great seventeenth century philosopher, René Descartes, in the Discourse on the Method, presented rules pertaining to methods of conducting scientific research, gathering information and reaching synthesizing solutions. They are nowadays accepted as universal and used in various areas of knowledge.

The major rules of methods, according to Descartes, are expressed as follows [1]:

- The first rule says that assessment of facts (research subjects) should be reliable, and the investigator should record only the facts, and not what he considers as facts. This is a principle that is applied in establishing the facts for a diagnosis of a status quo, and then in solving problems and formulating reliable conclusions about the status quo (critical assessment and analysis), and creating projects of changes.

- The second rule it is a method of analysis, which is regarded as a scientific method of recognizing the reality. Introduced for the first time by Taylor to investigate the course of work, this method allowed to accurately recognize the reality, to determine deficiencies and to design a new reality.
- The third one it is a universal method of scientific synthesis used in all fields of knowledge, but also in the classic Le Chatelier's organizational cycle [6, 19] when creating concept of a new organization.
- The last one it is a principle of strict registration and inspection for the sake of creating new reality. The acceptance of this rule is proven by the fact of creation of numerous techniques for event registrations in a graphic, tabular or mathematical form.

Every rule of the Cartesian method has an equivalent in methods empirically developed by the authors of the scientific basis of management organization, which can be defined, with certain extent of generalization, as diagnostic, analytical, synthesis, and maintenance and control phases of the research method.

The use of the seventeenth-century methods of rational, Cartesian's conduct combined with practical experience of the turn of nineteenth and twentieth century, contributed to formation of a classical method of organizational proceeding. A starting point for a general method of organizing activities were Taylor's works, who proposed for a manufacturing facility management a cycle of conduct, called an "elementary analysis" or "methodology of work process research". The first organizational methodology involved the following steps [10–12]:

- division of investigated process into the smallest elements,
- observations and measurements,
- filtering analysis, which aimed to keep essential elements in the process and to eliminate any unnecessary ballast,
- organizing the process and determining standard times of realization.

It was reflected in a so-called "organizational cycle" of Le Chatelier, which for many years was the basis of organizers' proceedings. It consisted of five stages [9, 11, 13]:

- choosing a goal to be achieved,
- analyzing resources and conditions which have to be used (created) to achieve that goal,
- preparing the resources and conditions which were found necessary,
- completing the goal according to a plan,
- controlling the results.

A study of working methods consists of recording, analysis and evaluation of existing or designed work practices. The goal of the study is to find and use the most effective methods of work. The set of activities related to the study of the methods of work includes [8, 10–12]:

- selection of a goal and object of research,
- gathering (registration) the facts,
- critical analysis and evaluation,
- designing a new method,

- implementation of the new method,
- monitoring of the development of the new method.

5 Typology of Methods of Organizational Problems Solving

In the literature of the subject the terms "strategy", "methodology" and "approach" are used interchangeably to define a general method of organizational problems solving.

The first typological attempts distinguished: classical, diagnostic, social, systemic, prognostic and situational approaches [10].

Another classification [14, 16, 17] encompasses three basic approaches called analytical method, synthetic method and situational method.

In the analytical method (diagnostic) a base of creation is a detailed analysis of existing system components. It is based on collecting and registration of characteristic features of the existing organizational solution. A current state is a starting point for a future project, which in the most cases comes down to a rationalization of organization and assumes solving the deviation and optimization problems.

In the synthetic method (prognostic) the starting point is a concept of a new (ideal) system, usually completely different from existing ones. All preliminary stages are skipped here, and taken into consideration are functions (goals) of a new system.

Situational approach is understood as a need to adjust the organization to internal and external conditions of its functioning. That makes it impossible to discuss the universal ways of creating and managing organizations.

An interesting attempt to systematize the methods of organizational problems solving is its "strategic" division into two groups: ideological and structured. The ideological methods, which incorporate the essential idea of organizational proceeding, could be called an "approach". The structured methods, containing further specification of steps (stages, phases) of conduct and possibly a specification of principles, methods, techniques and indications corresponding to individual steps, would be called "general methodology" [10].

The general methodology of solving organizational problems, may be based on three types of approaches [16]:

- descriptive-improving,
- functional-modelling,
- diagnostic-functional.

A descriptive-improving approach is characterized by the fact that the leading position in organizational proceedings is taken by registration of an actual state. An example of such approach is Taylor's elementary analysis. In this approach, empirical data collected in a course of observation is subjected to a critical analysis and evaluation in order to find possibilities of improvement.

General methodology of organizing, based on descriptive-improving approach, is usually called in literature a classical or diagnostic approach.

A major role is played by registration of facts and critical analysis and evaluation of a current state, that is why a lot of attention is paid to sources and methods of gathering information. In methodologies based on a descriptive-improving approach, the source of information of critical importance is believed to be the functioning of the analyzed organizational system. Data regarding this issue is obtained with a use of various methods and techniques such as direct and indirect observation, interview.

A functional-modeling approach – an organizer is thinking here: what purpose does an organization system serve? This approach prefers the method of idealization. An example of this approach in organizing is a method of ideal solutions of Nadler.

General methods of organizing, based on a functional-modeling approach, in the literature are usually given the name of systemic methods. Their creation is associated with limitations of descriptive-improvement approaches. First attempts to overcome the limitations were undertaken together with a use of operational research to the analysis of organizational systems. Construction of mathematical optimization models determined a major change in a scope, selection and methods of gathering information about analyzed organizational systems. The entering values of economic parameters to a previously constructed general model, allowed to define the optimal organizational solutions.

Another trend, beside operational research, which paved the way for functional-modeling approach in organizing, was value analysis. Starting point for changes in an analyzed system should be not as much the registration of an existing situation but the identification of functions performed by the system.

A diagnostic-functional approach – a critique of functional-modeling approach and difficulties and even failures in its practical application caused the methodological concepts to emerge, which sought to accommodate a descriptive-improving approach with a functional-modeling approach. The combination of Taylor's classical approach with Nadler's concept of ideal solutions gave rise to a new organizational approach, which used identification and analysis of functions of organizational systems, and even the method of idealization in finding optimal solutions, starting from a detailed description and analysis of the existing state.

To conclude the above presented general methods of solving organizational problems, it can be attempted to systematize organizational activities containing certain stages, for which the starting point is a formulation of a goal and the final point – obtaining positive results. Basic steps consist therefore of the following four phases [16]:

- identification of the problem and diagnosis,
- searching for solutions,
- making a decision,
- evaluation of effects of changes.

A diagnosis phase aims at formulating a problem as a result of analysis and diagnosis of the existing state. It defines the research objective and constraints that may occur in its solving, criteria that will be taken into account in evaluation of solutions' variants. This phase also encompasses a preliminary study, which task is to determine the nature, size and complexity of the problem and finally the scope and nature of changes that should be implemented as a results of the research procedure.

A research phase – collected, compiled and analyzed information and resulting conclusions are the basis for creating variants of concepts of problem solutions. This phase should also include an initial assessment and selection of variants of applicable concepts and their arrangement according to previously accepted criteria.

A decision making phase includes choosing one of the previously compiled and evaluated variants of solutions. The chosen variant should be carefully designed and implemented in practice.

An assessment phase is related to observation of functioning of the new solution and a revision, if needed.

6 Subcontracting Phase in IT Production Management System

A subject of the paper is a model of production process in IT production management system, presented in simplified form of items flow diagram through technological operations and stores between operations.

To properly understand the essence of the discussed process, it should be clarified that each phase of the production process in the IT system consists of three elements: a production line and two stores, one located in front of the line (shop store) and another one behind the line (store). In the store in front of the line there is a material, components or semi-finished products depending on phase of the production process, and in the store behind the line there are finished products (items) within a specific phase of the production process. The production line is a set of technological operations defined as a one-way flow.

The material needed for production in the IT system is moved from the main warehouse to the appropriate shop store in front of the production line within the specific phase of the production process. Then a production order for the line is opened. At the same time a purchase order (PO) is placed for a subcontracting operation for the products (items) manufactured on the production line mentioned above. After the subcontracting operation performed the items are received to the warehouse in the IT system, and strictly speaking they are registered in the shop store in front of the line. Finished products (items) are registered in the store behind the line or directly in a shop store in front of production line next phase of the production process, when the items are further processed. The process mentioned above is shown in the Fig. 1.

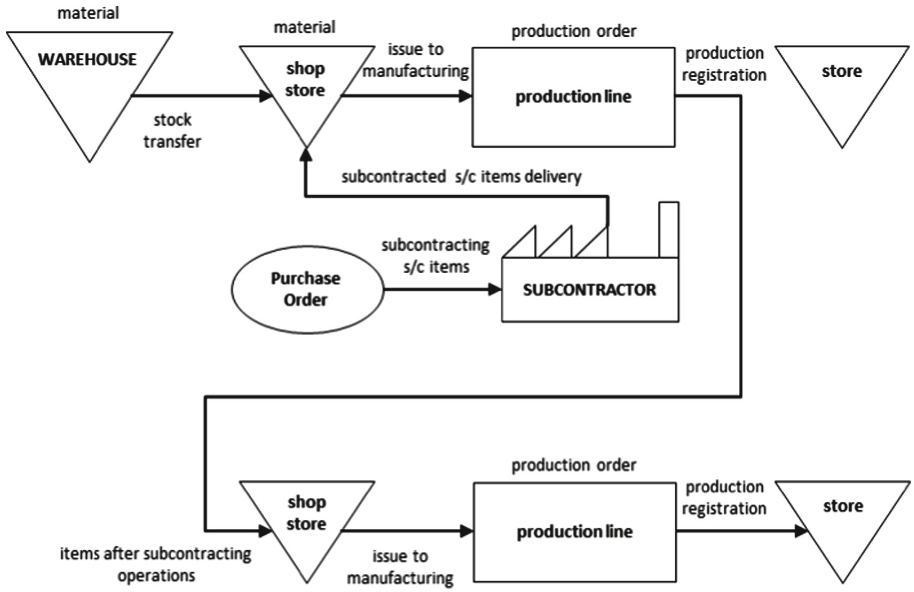

Fig. 1. Items flow diagram in a model of production process in IT system (subcontracting phase - current state)

Analyzing the production process model one can notice a lack of detailed information about various stages of the subcontracting process in the IT system. The generalness level of the process gives only a possibility to read from the placed purchase order (PO) information about the items quantity sent to subcontracting, on the other hand there is no data on the items quantity, that have returned from the subcontracting, because the receiving to shop store process of the items does not change the stock level. The coming back from subcontracting items are not issue to production like other materials or components, but they "disappear" during the shop store process receiving, and a cost of the subcontracting service is included in the production line costs.

Should be clarified here what the product structure (bill of material) looks like. The final product, for the production process phase mentioned above, has got two components in its structure: a material and the subcontracting item with a prefix "s/c". Setting parameters in the IT system contributes to the fact that the finished product registration in the store behind the production line causes an automatic diminishing of the material level in the shop store. The s/c item stock level in the shop store is not diminished by the IT system, its inventory is always null. From a production planning point of view, subcontracting process control in the IT system is inaccurate.

7 Improvement Method of Subcontracting Phase in IT System

The new improved model of the production process in the IT system must provide information on various stages of the subcontracting process from the point of view of the IT system mentioned.

Figure 2 presents a proposal to improve the mentioned process. The material needed for production in the IT system is moved from the main warehouse to the appropriate shop store in front of the production line within the specific phase of the production process. Then a production order for the line is opened. At the same time a purchase order (PO) is placed for a subcontracting operation for the products (items) manufactured on the production line mentioned above (items with the prefix “s/c”). The material located in the shop store (in front of the line) is now moved to the store (behind the line) so to the finished product store within this phase of the production process, along with a note on subcontracting. A case when the material for production is located in the store of finished products, it is a signal that an error, anomaly appeared in the IT system in a normal situation. Usually it is caused by human factor. Now in the new model it is an information the material was sent to the subcontractor. This is the information of both qualitative and quantitative nature because it provides information of fact that the real shipment was done, and about the volume as well.

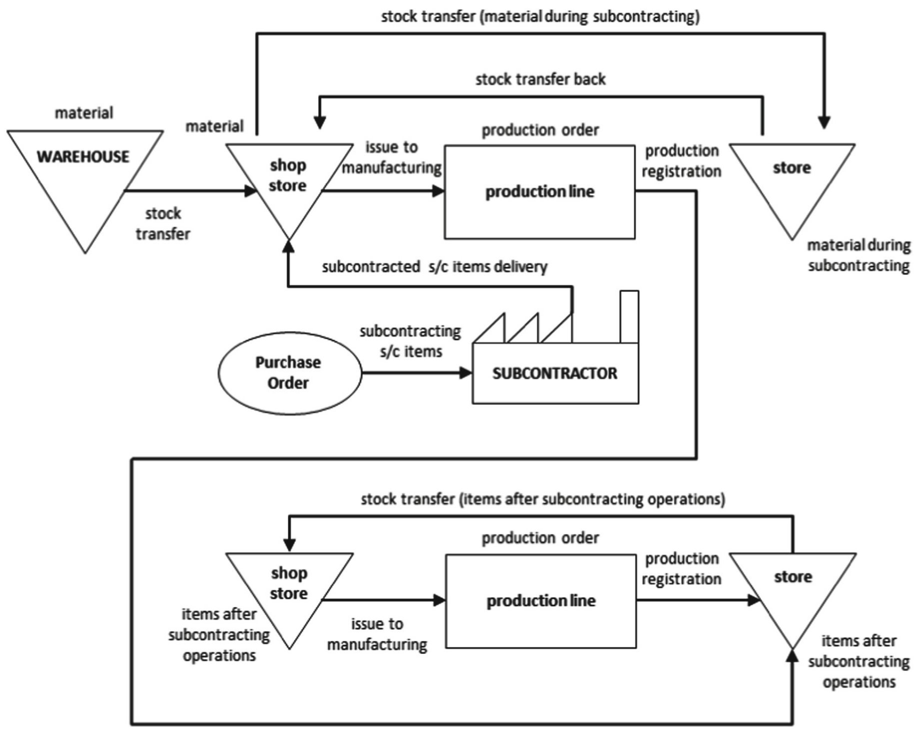

Fig. 2. Items flow diagram in a model of production process in IT system (subcontracting phase - improved state)

After the subcontracting operation performed the items are received to the shop store in the IT system and “disappear”, and a cost of the subcontracting service is included in the production line costs. At this point it is necessary to move the material back from store (finished products store) to the shop store (in front of the line). The material returned to the right place from the IT system point of view. The finished product registration in the store behind the production line causes an automatic diminishing of the material level in the shop store. The subcontracting item stock level in the shop store is not diminished by the IT system, its inventory is always null. An originality is now the place where the finished products are registered now in the IT system, in fact the products that have just returned from the subcontracting. They are registered now in the store of finished products next phase of the production process along with a note on subcontracting. The case is analogical that was described earlier about the material moved (stock transfer) to the finished product store. It is of course the signal that an error, anomaly appeared in the IT system in a normal situation. Now this information provides knowledge that the items returned from the subcontracting service and they are available for the next phase of the production process. Parameter settings in the IT system make the material, components, semi-finished products can be released for production only from shop store, so move the items returned from subcontracting from the store to the shop store remains to be done.

8 Conclusions

Presented in the article the model of the production process in the IT production management system, shown in simplified form of items flow diagram through technological operations and stores between operations, provided with the knowledge about quality of information given to the IT system users involved in planning process, manufacturing control and production management.

A specific principle of the IT system operation, settings parameters and lack of knowledge about a way of subcontracting phase of the production process conducting in the IT system caused that the original model was designed in a very general way. The IT system did not provide detailed information about each stage of the subcontracting process. The concept of making material and subcontracting items transfer between shop store and store provides quantitative and qualitative information of particular stages of the subcontracting process. The items flow through technological operations and stores between the operations, is now more readable and precise. It contributes to easier and more effective planning, control and management of not only the subcontracting process in the IT system, but also other related processes.

To improve the operations in the IT system, the analytical (diagnostic) approach was used, also known as a descriptive-improvement approach. The carried out analysis of components and operation principles of the existing production process in the IT system model, was based on collection and registration distinguishing features of the current solution. The empirical data gathered during observation is subjected to critical analysis and evaluation in order to find opportunities for improvement. The current state had become a starting point for designing the future project.

References

1. Descartes, R.: Rozprawa o metodzie. PWN, Warszawa (1988)
2. Gilbert Daniel, R., Stoner James, A.F., Freeman Edward, R.: Kierowanie. Wydawnictwo Naukowe PWN, Warszawa (2011)
3. Griffin, R.W.: Podstawy zarządzania organizacjami. Wydawnictwo naukowe PWN, Warszawa (2017)
4. Kisielnicki, J.: Zarządzanie organizacją. Zarządzanie nie musi być trudne. Szkoły zarządzania i prekursorzy teorii organizacji i zarządzania (2004)
5. Klincewicz, K.: Zarządzanie, organizacje i organizowanie – przegląd perspektyw teoretycznych. Wydawnictwo Naukowe Wydziału Zarządzania Uniwersytetu Warszawskiego, Warszawa (2016)
6. Koźmiński, A., Piotrowski, W.: Zarządzanie. Teoria i praktyka. PWN Warszawa (2013)
7. Lachiewicz, S., Matejun, M.: Ewolucja nauk o zarządzaniu. Podstawy zarządzania (2012)
8. Lis, S.: Organizacja i ekonomika procesów produkcyjnych w przemyśle maszynowym. PWN, Warszawa (1984)
9. Martyniak, Z.: Prekursorzy nauki organizacji i zarządzania. PWE, Warszawa (1989)
10. Martyniak, Z.: Metody organizacji i zarządzania. Wydawnictwo Akademii Ekonomicznej, Kraków (1999)
11. Martyniak, Z.: Historia myśli organizatorskiej. Wydawnictwo Akademii Ekonomicznej w Krakowie (2002)
12. Martyniak, Z.: Nowe metody i koncepcje zarządzania. Wydawnictwo Akademii Ekonomicznej w Krakowie (2002)
13. Mendel, T.: Wybrane problemy ewolucji nauki o organizacji i zarządzaniu. Wyższa Szkoła Marketingu i Zarządzania, Leszno (1995)
14. Mikołajczyk, Z.: Techniki organizatorskie w rozwiązywaniu problemów zarządzania. Wydawnictwo Naukowe PWN, Warszawa (1999)
15. Mioduszewski, J.: Metody organizacji i zarządzania. Wydawnictwo Expol, Olsztyn (2013)
16. Siemieniak, M.: Identification of the Production Working Time Losses. Publishing House of Poznan University of Technology, Poznan (2014)
17. Skalik, J. (ed.): Metody i techniki organizatorskie. Wydawnictwo Akademii Ekonomicznej we Wrocławiu, Wrocław (2001)
18. Stabryła, A.: Podstawy organizacji i zarządzania. Podejścia i koncepcje badawcze. Wydawnictwo Uniwersytetu Ekonomicznego, Kraków (2012)
19. Szymańska, K.: Kompendium metod i technik zarządzania. Wolters Kluwer, Warszawa (2015)

Clothing Distribution Optimization for Rental Company Warehouse

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Abstract. This work considers the problem of choosing the right strategy for clothes distribution in a rental company warehouse. The basic criterion for the clothing arrangement assessment is, among others, optimization of employees' working time, and thus ergonomics. It is assumed that the incoming orders stream is known.

Keywords: Rental company · Warehouse · Modeling and optimization Ergonomics

1 Introduction

In many practical cases the problem of modeling and searching optimal strategy in manufacturing is often considered [1–4]. In this paper we consider the problem of determining the optimal method for clothing arrangement in a rental company warehouse shelving. One of the criterion for the clothes placement assessment, among others, is the optimization of employees' work time and thus ergonomics, with known incoming streams of orders to the warehouse. The effective and ergonomic allocation of clothes in warehouse racks should also lead to maximizing the use of storage capacity. This leads to minimizing the time needed for faultless finding and picking up of clothes. The system should indicate order of picking up from the warehouse so that the process is effective, and at the same time ergonomic. It should also determine whether the clothes layer should be counted from the bottom or top of the clothes stack.

The aim is to develop an algorithm that will show which warehouse strategy of operating is optimal for the current service, taking into account the warehouse capacity and the unit production cost for new clothes for the inventory.

Business processes of warehouse operations have been designed. A model and optimization problem are built to search solution with the following assumptions:

- clothes distribution in the warehouse,
- characteristics of the incoming stream of warehouse orders,
- determined the effective method of warehouse personnel work.

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The analysis of work efficiency of warehouse personnel was carried out, taking into account the value of ergonomic parameters related to the activities performed. The results are presented in different forms like charts and tables. They show the way of examining:

- methods of clothes distribution in the warehouse,
- and algorithms of the warehouse team activity procedures, from the point of view of time and ergonomics.

2 Clothing Rental Company

The company deals with the rental of work clothes. Customers are offered the following services:

- Work clothing - the company provides different models of workwear such as jackets, t-shirts, shirts, trousers, aprons, etc. The sizes of clothing are standardized, but in the case of people with special sizes, clothing is tailor-made. A company employee takes measurements of people working at the client's. There are also documents in which you can enter typical sizes of clothes for individual people in advance. Such clothes are completed for the client's employees.
- In many cases, clothing is seasonal, which means that other items of clothing are issued for the summer season and another for the winter season.
- Each piece of clothing has an RFID chip sewn in, and the RFID tag identifies one person to whom the clothing refers.
- Rental of work clothing includes the number of sets and the assortment characteristic for a given contract with a given client.
- Installation of clothing cabinets in the workplace of employees, therefore at clients. Each employee has a closed bin in one of the wardrobes, from which he takes work clothes.
- Installation of so-called drop-out cabinets - the customer's employee throws used and soiled work clothing items into the drop-in cabinets.
- Collecting workwear from the customer - an employee of the rental company (driver) arriving at the customer's, puts in the clothing cabinets clean and possibly repaired clothing into the bins with employee's name printed.
- Description of the clothing being taken - a rental company employee (driver), in agreement with the responsible employee of the customer, prepares a list of work clothing taken from the cabinets. He also accepts certain documents from the client, in which various types of important information are posted, for example: the loss of an employee from the client's company, the adoption of another, for which you need to prepare workwear, remarks for invoices, etc.
- The driver delivers clean clothes to the customer and receives dirty and possibly damaged clothing once a week on the same day. The driver overcomes a certain route on which he has several clients to deal with. Drivers have a schedule with different routes for every week day.

- Parcels with clothing for clients are collected from the warehouse, in which special large bags are prepared with the clothes description and the customer's name.

As part of laundry services and minor repairs, the company performs the following activities:

- Clothing, which goes to the rental company, is sorted in terms of the degree of soiling.
- After sorting the clothing, which is put into containers, it is subject to the washing process. The rental company has a number of industrial washing machines, to which all necessary chemicals are automatically distributed from tanks. The authorized employee after inserting the clothes into the washing machine, chooses the right washing program.
- Washed clothes go through gas dryers reducing its moisture to about 10–15%. After washing and drying, clothing is hung on hangers and placed on three rails of an automated sorting line. Then the further drying occurs.
- After these treatments, clothing, still on hangers, moves on three rails to people who control the state of clothing, including the quality control and cleanliness control. It should be remembered that the clothes moving on rails are constantly registered by RFID antennas. In the case where certain items of clothing are not well washed, the controlling person marks it on the touch screens and returns the clothing to be washed again. If he finds damage to clothing, he transfers these items for repair (a given piece of clothing comes off the automatic line and is transferred in baskets to the garment repair point.) The garment is also attached with a damage description card and RFID identifier. The description of the damage is in some way normalized, because the quality control worker touches a screen with a clothing item on it, and marks the place of damage adding other relevant information.
- Damaged clothes are handed over to the repair point on an ongoing basis, where repairs are carried out on site as far as possible. If this action is successful, the repaired clothing is placed on the rails for further service. If the repair has to be more specialized, it is packaged and sent to a professional repair point. Documents describing the performance of additional services are always created with an estimation of their level – for a purpose of determining additional fees.
- If there are no comments to the washed clothes, it is sent to the sorting machines. Without going into details, this clothing moves on the rail system, and the sorting algorithm leads to the hanging of clothing sets associated with a single person at the end. The set is subject to semi-automatic pressing, as well as to folding and packing. The created package is described by the name of the employee, the name of the customer, etc.
- Packages for a given customer are put into special large bags, which are described with the customer's name. If there are no certain items of clothing for a given company because they have been put in a second wash or minor local repair (usually some percent of clothing items are subject to additional service), then after additional service they are added to the bags that wait for delivery to a given customer.
- At the same time, documentation is sent automatically to the Customer Service Department.

3 Work Clothing Storage

Every warehouse contains wardrobes with new clothing sewn for clients and measuring collections for measuring customer employees. These are sliding wardrobes consisting of:

(a) units,
(b) shelves,
(c) bins - usually 4 (or 2 for jackets),
(d) layers (overlapping pieces of clothing).

Another warehouse is sliding wardrobes with clothing received from customers. The reason for this is different: the customer's employee has been fired, the employee has significantly changed his dimensions, the contract with the client is over and he does not refuse to buy used clothing, etc. These cabinets also consist of:

(a) units,
(b) shelves,
(c) bins,
(d) layers (overlapping pieces of clothing).

Work clothes are placed in special storage cabinets (Fig. 1.)

Fig. 1. View of typical sliding cabinets

The warehouse will mainly be subject to the process of optimizing the deployment of clothing, because the main warehouse service processes take place there, with the exception of laundry processes, packaging and delivery. The warehouse workers serve a number of activities, including assembling RFID markers, assigning them to employees, folding clothes for new employees, etc.

Furthermore, the warehouse workers have access to the warehouse system, which results in orders for storage services for a given day. Persons operating the system are in principle directing work in this room and working with clothing in warehouses. They also check the condition of clothing before completing it, and all details, including, for example, the required patches with customer's logo or employee's name. They also have possibility to read the RFID tag and access the system, in which the warehouse employee has a list of employees of whom he assigns clothing items.

In principle, work in the storage room is carried out according to the following rules:

- There is a new order: complete clothing for a customer employee (both newly hired, and for who has significantly changed their size) or there are more customers, so there is a group of customer employees for whom you need to complete clothing.
- It may also be an order to add a piece of clothing to the person already employed, because, for example, the previous one has been used up.
- Typically, 10–20 orders per employee are served daily in the warehouse room.
- The following sequence of actions is repeated for each employee of the client:

  (a) Is this a new employee?
  (b) Is there a provision in the contract about getting a new (unused) clothing? If there is no such clothing in the warehouse, a sewing order is sent.
  (c) The new clothing has an RFID chip, its correct operation is checked, so it is possible to assign an item of clothing to the customer's employee.
  (d) Each time, complete sets of clothes are transferred from the room to the end of the washing line on hangers on rails and in this way are subject to the normal packing procedure for a single employee of the customer in wrapped packages and the packages are folded into bags for the customer.

- If it is possible to match the used clothing for the customer's employee, then the warehouse manager searches for the appropriate clothing items in the system.
- You have to remember that this clothing has several features that eliminate possible assignments: color, shade of color, size (S, M, L,…), height, etc.
- If there is no indication of an available clothing element in the system (it happens very rarely), then an order must be issued to sew the item of clothing.
- If not, the warehouse employees go to the warehouse and pick up, according to the order, clothing items to be completed. Later, they read RFID identifiers from the garment items and assign them to the client's employees for whom the clothing set is being completed. The next procedure is continued as described earlier.

The following elements of the warehouse operation are taken into account:

- A set of orders is set once a day with minor (negligible) modifications.
- There is no stream of continuous orders, only a set of orders for a given day (10–20).
- Employees give inquiries to the system regarding items of clothing.
- The system shows found elements matching the completed set for the customer's employee.
- The employee directing the work in the warehouse marks one. The system shows the wardrobe, bookcase, shelf, bin and layer where the selected item of clothing is placed.
- Gathering all the information about items of clothing taken from the warehouse for the day, the warehouse worker goes alone or with the helper to pick up items of clothing.
- All items of clothing needed for a given day are collected. Then, the assignment procedure (linking the RFID identifier with the customer's employee) of the clothing element to the customer's employee is initiated. After checking the condition of the clothing item on the table, this element is added to the prepared set.
- The system registers this allocation.
- The same applies to the canceled items of clothing. They have to be put on shelves in the warehouse. This is also done manually without the suggestion of the system, but it is shown in the system where this item of clothing is located with given properties (type, color,…) and where it was folded - wardrobe, bookcase, shelf, partition and layer (usually on the top layer).
- The system registers this fact after providing this information by the warehouse employee and from that time it can indicate this garment in the case of subsequent requests (orders).
- Clothing is placed in storage cabinets and each item of clothing has its place in a specific cabinet (wardrobe, rack), unit, shelf, bin and it is placed on the subsequent layer (Fig. 2.).

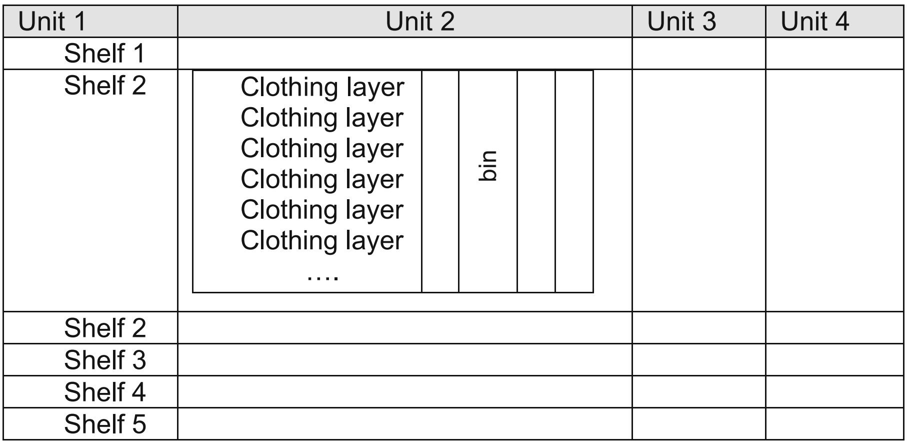

Fig. 2. Storage units' configuration

4 Modeling and Optimization of Clothing Distribution

Let's assume that we are dealing with items of clothing numbered:

$$N = \{1, 2, 3, \ldots, n, \ldots, N\} \tag{1}$$

The whole content of wardrobes (racks, units, shelves, bins and layers can be defined by a multidimensional matrix:

$$\boldsymbol{S} = [\boldsymbol{s}_{\boldsymbol{wusbl}}]_{\boldsymbol{WxUxSxBxL}} \tag{2}$$

where

W –	number of wardrobes,
U –	number of units,
S –	number of shelves,
B –	number of bins,
and L –	number of layers.

Then, assigning all items of clothing to individual elements of the warehouse is impossible to analyze due to the size of the decision variable.

Assuming the fact that we arrange certain clothing sets for defined elements:

- wardrobe (rack),
- unit,
- and shelf,

the decision variables are no longer such sizes and

$$\boldsymbol{X} = [\boldsymbol{x}_{\boldsymbol{wup}}]_{\boldsymbol{WxUxP}} \tag{3}$$

where w, u, s - appropriately numbered wardrobes, units, shelves in the rack.

Similarly, we number the sets of items of clothing (jackets, pants, shirts, t-shirt,…) of a special size:

$$\boldsymbol{Z} = [z_i]_{\boldsymbol{I}} \tag{4}$$

where z_i is the number of a set of i'th clothing items.

Then x_i is the number of the set that will be located in a given place, or in a binary form will be a vector:

$$\boldsymbol{x}_{\boldsymbol{wup}} = \left(\boldsymbol{x}_1^{\boldsymbol{wup}}, \boldsymbol{x}_2^{\boldsymbol{wup}}, \boldsymbol{x}_3^{\boldsymbol{wup}}, \ldots, \boldsymbol{x}_{\boldsymbol{j}}^{\boldsymbol{wup}}, \ldots \boldsymbol{x}_{\boldsymbol{J}}^{\boldsymbol{swup}}\right) \tag{5}$$

where

$$\boldsymbol{x}_{\boldsymbol{j}}^{\boldsymbol{wup}} = \begin{cases} 1 & \text{when on wup'th - place is j'th set} \\ 0 & \text{when it is another case} \end{cases} \tag{6}$$

Then we are looking for the value of an X matrix that gives us the sought-after arrangement of individual sizes in the cabinet elements.

Let's assume that:

r_i - permissible number of layers of i'th elements on the shelf,

L_i - the number of i'th elements owned by CRL with the accuracy of a multiple of the number ri.

In this case, the decision variables have (symbolic in this case) simple limitations:

$$\sum_{w=1}^{W}\sum_{u=1}^{U}\sum_{p=1}^{P}\{x_{wup} = 1\} \cdot r_{jwup} = L_1 \tag{7}$$

$$\sum_{w=1}^{W}\sum_{u=1}^{U}\sum_{p=1}^{P}\{x_{wup} = 2\} \cdot r_{j_{wup}} = L_2 \tag{8}$$

$$\cdots$$

$$\sum_{w=1}^{W}\sum_{u=1}^{U}\sum_{p=1}^{P}\{x_{wup} = J\} \cdot r_{j_{wup}} = L_J \tag{9}$$

where $L_1 + L_2 + \ldots + L_J = N$.

If we assume that a one-day order is a vector:

$$y = (y_1, y_2, y_2, \ldots, y_j, .., y_J) \tag{10}$$

where y_j - the number of required elements of clothing types for a given day, then we have the space of demand vectors Y, $y \in Y$.

Then, the criteria for assessing the distribution of clothing items in the cabinets are:

$$f_y(X) = \sum_{w=1}^{W} sign\{x_{wup} = w\}, y \in Y \tag{11}$$

which means the number of sliding racks.

We strive to designate such an X * to

$$f_y(X^*) = min\left\{\sum_{w=1}^{W} sign\{x_{wup} = w\}\right\}, y \in Y \tag{12}$$

This criterion should minimize the number of wardrobes to be moved.

We analyze the available focus points in the Y space (Fig. 3).

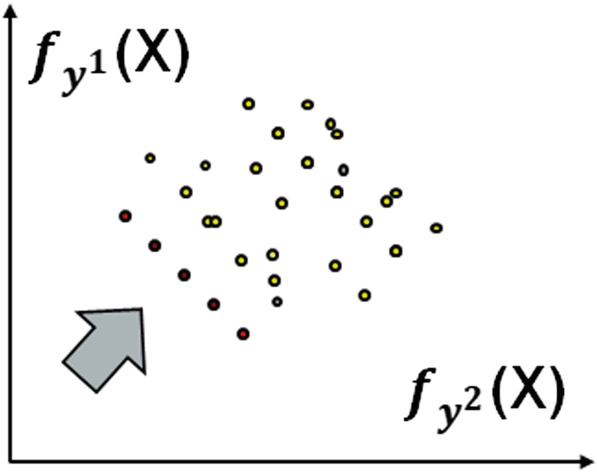

Fig. 3. Multicriterial space of solutions (X) evaluation

If we know (from data in BD) the frequency β_y of the occurrence of different values of y vectors in one-day orders, the functions $f_y(X)$ are modified in the following way:

$$f_y(X^*) = \beta_y \cdot min\left\{\sum_{w=1}^{W} sign\{x_{wup} = w\}\right\}, y \in Y \tag{13}$$

We receive the task of multi-criteria optimization of the distribution of clothing sets in storage cabinets. It is possible to show many practical problems and methods for constructing and solving such problems [5–9].

5 Genetic Algorithm for Solving the Problem

There is another way to determine the distribution of clothing sets in storage cabinets using the genetic algorithm [10]:

- We generate a number of initial locations $\{X_1, X_2, X_3,\ldots, X_P\}$ by creating a basic population.
- Different types of mutation operators are constructed (changes in the distribution of sets in the cabinets based on individual locations). Idea of such class of mutation operators is shown on figure Fig. 4.
- Different types of crossover operators are constructed (changes in arrangement of sets in wardrobes based on pairs of locations). Idea of such class of crossover operators is shown on figure Fig. 4.

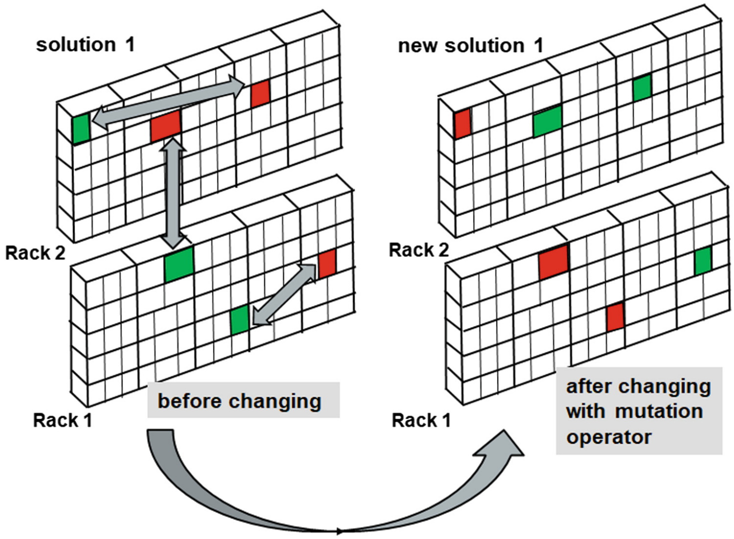

Fig. 4. Modification of a single solution after applying the mutation operator

- We generate many vectors as one-day order of demand for the download or location work clothes form/into warehouse wardrobes.
- We calculate the expected value of function

$$f_y(X) = \sum_{w=1}^{W} sign\{x_{wup} = w\}, y \in Y \tag{14}$$

values obtained from individual generated vectors y
- We select elements of the next population by selecting such locations to minimize functions

$$f(X^*) = \beta_y \cdot f_y(X) = \beta_y \cdot min\left\{\sum_{w=1}^{W} sign\{x_{wup} = w\}\right\}, y \in Y \tag{15}$$

- In the selection procedure, we choose the best locations.
- We repeat this action as many times as possible until the stop sign of the procedure, which can be several different types.

Using this algorithm, it is possible to obtain a suboptimal solution in a relatively short time to determine the distribution of clothing in the warehouse (Fig. 5).

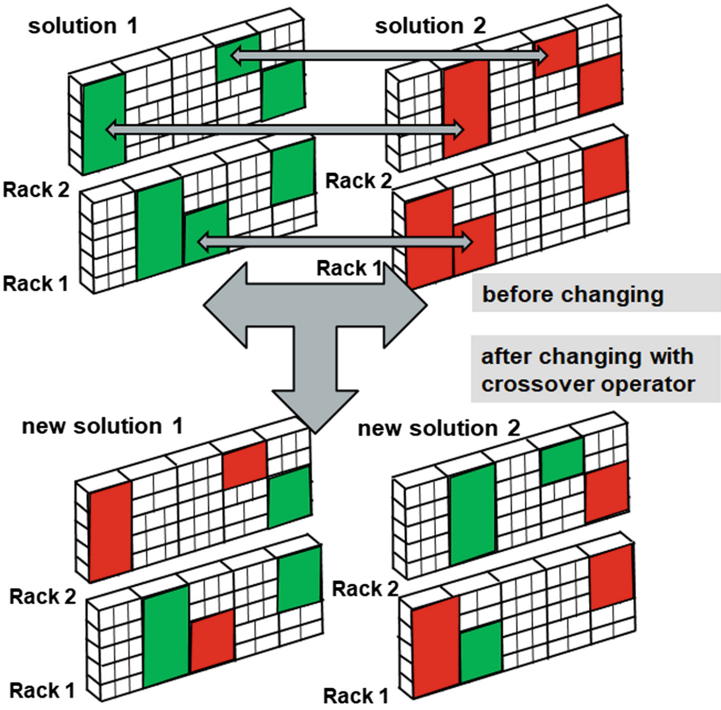

Fig. 5. Modification of a pair of solutions in the population after applying the crossover operator

6 Conclusion

The work describes the behavior of people in the warehouse of a company dealing with the rental of work clothes. It has been shown that clothes in storage wardrobes can be arranged in such a way as to minimize their movement while collecting and folding clothes there.

A model of clothing distribution in storage cabinets has been presented. The task was to optimize the distribution of clothing in wardrobes, units, shelves and levels. A method for solving the formulated optimization task was proposed.

References

1. Pinedo, M.L.: Scheduling. Theory, Algorithms and Systems. Springer, New York (2008)
2. Pinedo, M.L.: Planning and Scheduling in Manufacturing and Services. Springer, New York (2005)
3. Pochet, Y., Wolsey, L.A.: Production Planning by Mixed Integer Programming. Springer, New York, London, Heidelberg (2005)
4. Simchi-Levi, D., Chen, X., Bramel, J.: The Logic of Logistics. Springer, New York (1997)
5. Nowicki, T., Waszkowski, R.: The method for solving productivity oriented scheduling problem. Research in Logistics and Production, Poznan University of Technology (2013)

6. Nowicki, T.: Linear mixed equivalent of a stochastic scheduling problem with different processors. Biul. WAT/4/1994 (1994)
7. Nowicki, T.: Stochastic bi-objective scheduling problem in a multiprocessor computer system. In: The 5th International Workshop on Project Management and Scheduling, 11–13 April 1996
8. Nowicki, T., Kiedrowicz, M., Waszkowski, R., Wesołowski, Z., Worwa, K.: Optimization of the document placement in the RFID cabinet. In: MATEC Web of Conferences 7 02001 (2016). https://doi.org/10.1051/matecconf/20167602001
9. Nowicki, T., Waszkowski, R.: Productivity oriented cooperative approach to scheduling IT project tasks. In: Saeed, K., Homenda, W., Chaki, R. (eds.) 16th IFIP International Conference on Computer Information Systems and Industrial Management (CISIM), Lecture Notes in Computer Science, LNCS-10244, Computer Information Systems and Industrial Management, Jun 2017, Bialystok, Poland, pp. 354–365. Springer International Publishing (2017)
10. Goldberg, D.E.: Genetic Algorithms in Search, Optimization & Machine Learning. Addison-Wesley Publishing Company, Inc., Boston (1989)

Impact of Office Design on Satisfaction of Government Employees in Laguna Provincial Capitol, Philippines

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Abstract. Satisfaction of employees in the workplace is influenced by many factors such as compensation, career growth and development, interaction to peers and office design. Several tools were used in this study in determining the impact of office design on the satisfaction of government employees in the Laguna Provincial Capitol. Different office types present inside the said institution were first recognized, and seven office types were identified as follows: individual office, shared room, small open plan, medium open plan, large open plan, cubicle, and half partition. In this study, importance- satisfaction analyses were conducted to determine what office design elements should be given priority per office type. To significantly improve satisfaction of employees on their office design, the management should focus on the office design elements that fall on the second quadrant of the Importance Satisfaction Matrix, as these elements have relatively high importance for the employees; however, satisfaction of employees on these elements is relatively low.

Keywords: Office design · Importance- satisfaction analysis
Employee satisfaction · Government employees

1 Introduction

Employee satisfaction is basically a factor in employee motivation, employee goal achievement and positive employee morale in the workplace that measures what an employee feels towards his or her job and working environment [1]. Increasing employee satisfaction, in a way, can increase employee productivity, responsiveness, quality of work, and customer service [1]. With this, firms and organization must make intensive efforts to increase satisfaction of their employees. Similarly, more satisfied employees do better at work [2].

The following factors are significant to the overall employee satisfaction: pay, work, environment, and co-workers; as well as having adequate work equipment, resources, and training opportunities and an equitable workload [3]. Similarly, the following factors certainly have meaningful impacts on job satisfaction: achievement, feedback, control, small daily hassles, organizational support, recognitions, physical office environment, flexibility, relationship to immediate supervisor, and work- life balance [4].

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Undoubtedly, the office or the environment where the employee works, has an obvious impact to the satisfaction of the employee. In fact, "those employers who ignore the evidence of office design as an enabler of staff satisfaction and performance risk the loss of key staff and ultimately business success [5]."

Good office designs, in general, make satisfied employees, while the bad ones impact satisfaction of employees negatively. Offices must be designed in such a way that all the needs of employees are fulfilled in order to make best use of their productivity and satisfaction [6]. The working environment of employees contributes about one-fourth to job satisfaction level, second to rewards and recognitions [7]. It was reported that the design of an office directly affects the performance and job satisfaction of staff, which is responsible for 24% of job satisfaction, 5% of individuals staff performance and 11% of team staff performance [5].

There were various studies conducted concerning job satisfaction of practitioners and researchers. However, little attention has been focused to study satisfaction among government employees [8].

Understanding these, the study thus intended to determine the impact of office design on satisfaction of government employees in Laguna Provincial Capitol, Philippines.

Laguna is one of the five provinces in the CALABARZON region of the Philippines, along with Cavite, Batangas, Rizal, and Quezon. It is situated southeast of Metro Manila, south of the province of Rizal, west of Quezon, north of Batangas and east of Cavite. It embraces the southern shores of Laguna de Bay, the largest lake in the Philippines. It comprises 24 municipalities and 6 cities.

The provincial capitol of Laguna, called the Laguna Provincial Capitol, is situated in Santa Cruz, the capital of the province. Inside the capitol are the Office of the Governor of Laguna and some diverse functional offices of the Government.

Considering the office type classifications on previous related studies, the office types present in the Laguna Provincial Capitol are as follows: individual office, cubicle, half partition, shared room office, small open-plan office, medium open-plan office, and large open-plan office.

1.1 Significance of the Study

It is of utmost importance to ensure that employees are satisfied with their jobs. Their satisfaction, however, is affected by numerous aspects. Though there are internal and external factors that may affect employee satisfaction, this study is particularly concerned with the working environment or the design of the office of the employees. Job satisfaction and productivity of employees have a significant relationship with employee's satisfaction to its physical working environment [9].

From a Likert scale of 1 to 5 (1 being not at all important and 5 being critically important, government employees of the Laguna Provincial Capitol rated office design at 4.04, on the average. They believe that office design is an important aspect of their job. Also, from a Likert scale of 1 to 5 (1 being very dissatisfied and 5 being very satisfied, office design was rated at 3.32. Yet, to increase this, there is a need to study first the impact of office design to the satisfaction of government employees under study.

Aside from determining the satisfaction of employees on office design elements (e.g. lighting conditions, acoustic conditions) for different types of office, the importance of each element to the employees were also determined. With this, this study can help the management determine which elements of office design per office type needs attention, in order for the satisfaction of its occupants to increase.

1.2 Scopes and Limitations of the Study

Knowing that satisfaction cannot be quantified using objective measures, subjective data are the primary basis of the results of the study, in which respondents rated the extent to which they find the given factors satisfactory. Standards of the respondents are apparently different among each other; therefore, the study is subject to cognitive bias.

Furthermore, since the study only covered the population of government employees in the Laguna Provincial Capitol, the results are only applicable to the said research locale. In other words, the results of the study will not be applicable to other populations, considering the fact that the population considered may have different satisfaction compared to them.

Lastly, since the study is concerned with the impact of office design to satisfaction of government employees in the Laguna Provincial Capitol, the respondents only included those who work inside an office with a designated workstation.

2 Literature Review

2.1 Office Types

Of a number of generic types of office layouts, two extremes are the private/individual office, in which there is a closed space/room for every occupant, and the open plan, in which workspaces are in a shared space [10]. Open plan office type can be subdivided into four styles such as cubicle, half partition, team enclosure, and one large open space [11]. On the other hand, in some studies, seven office types were identified in a contemporary office design as follows: cell-office (single office room); shared room office (2–3 people share room); traditional open plan office types which are the small open plan office (4–9 people share workspace), medium-sized open plan office (10–24 people share workspace), and large open plan office (25 or more people share workspace); and activity based office types which are the flex- and combi- offices [12].

The following office types are used by government employees in the Laguna Provincial Capitol, considering the aforementioned office type classifications: individual office, cubicle, half partition, shared room office, small open plan office, medium open plan office, and large open plan office.

2.2 Employee Satisfaction

The kind of attitude or feeling of an employee towards his or her job, known as employee satisfaction, somewhat reflects employees' perspective regarding the value or worth of a job relative to other jobs [13]. By maintaining an engaged and motivated workforce, satisfaction of employees is considered vital in facing the complex and continually-occurring challenges of maintaining productivity of the organization [14]. Employee satisfaction not just affect productivity but also the sense of morale and commitment of an employee towards the organization, serving as an avenue for employee's career advancement within the present organization without any thoughts of leaving the organization [14]. It can be said that making satisfied employees also means making productive, loyal, and committed employees.

2.3 Office Design

An office design can be considered good if it supports the needs of its occupants and if it serves as a conducive environment for the occupants to do their tasks well [15]. A favorable working environment gives the occupants a sense of pride in what they do [14].

From the study of Stallworth (1996), results show that office design can be a contributory factor in company's overall performance, as well as the individual performances of employees [14].

3 Methodology

Overall, there are 464 government employees in the Laguna Provincial Capitol who work inside an office with a designated workstation. As shown in Fig. 1, they were categorized according to their office type (e.g. individual, cubicle, half partition, shared room, small open plan, medium open plan, and large open plan).

Stratified sampling was used in the study. As mentioned earlier, the population was divided according to office types of the employees. The office types serve as the strata. A sample size calculator with 95% confidence level and 10% level of error was used to get the appropriate sample. The proportion of each stratum in the population was considered in getting the number of samples needed for each.

The major instrument used in data gathering was a researcher-administered questionnaire based on the objectives of the study. The questionnaire was divided into 5 parts: (1) respondent's sociodemographic information, (2) their nature of work, (3) factors affecting their job satisfaction, (4) importance of office design elements for their job, (5) their satisfaction on office design elements.

For the first part, sociodemographic information of the respondents were asked which includes the name, department, position, age, sex, civil status, highest level of educational attainment, and number of years working in Laguna Provincial Capitol. For the second part, the respondents were asked of their nature of work. For the third part, the respondents ranked thirteen factors that affect their job satisfaction from one (being the biggest contributor to their job satisfaction) to thirteen (being the least contributor). For the fourth and fifth parts, the respondents were asked to evaluate diverse office design elements on a five-point Likert scale of importance rating and satisfaction rating, respectively. Importance of the elements of office design for the employees were rated from

OFFICE	OFFICE TYPE						
	Individual	Cubicle	Half Partition	Shared Room	Open Plan		
					small	medium	large
Accounting	1		3				45
Administrator's Office			22	2			
Assessor's Office	1						25
Budget			14	2			
Engineering	2		7			17	
General Services	1					20	
Housing	1	2				14	
Human Resources					17	16	
Information System						12	
Legal Services	2	3	15				
Livelihood						12	
LTCATO	3		27				
Moral and Woman					6		
Office of the Governor	1	1	16	4	4		
Peace and Order	1			2	6		
Planning						14	
Provincial Information	1				10		
Public Affairs					6	12	
Sangguniang Panlalawigan and Office of the Vice Governor	2		17			11	
Sectoral Concern						11	
Traffic Management	1				7		
Treasury	1		15			18	
Youth Development						11	
TOTAL	18	6	136	10	56	168	70
GRAND TOTAL	464						

Fig. 1. Population of government employees in Laguna Provincial Capitol per office type.

not at all important to extremely important. On the other hand, satisfaction of employees on the elements of office design were rated from very dissatisfied to very satisfied.

The elements of office design considered in the study included six categories: furniture, equipment, workplace, workstation, ambient conditions, and privacy.

Importance-satisfaction analysis was used in identifying which office design elements should be given priority. For instance, the elements that were given the highest priority are those which are given the lowest satisfaction rating and are given the highest importance rating.

For each importance-satisfaction analysis, an importance satisfaction matrix was generated dividing the elements of office design into four quadrants: continued emphasis (above average importance and above average satisfaction), exceeding expectations (below average importance and above average satisfaction), opportunities for improvement (above average importance and below average satisfaction), and less important (below average importance and below average satisfaction). An example of the said matrix is shown in Fig. 2.

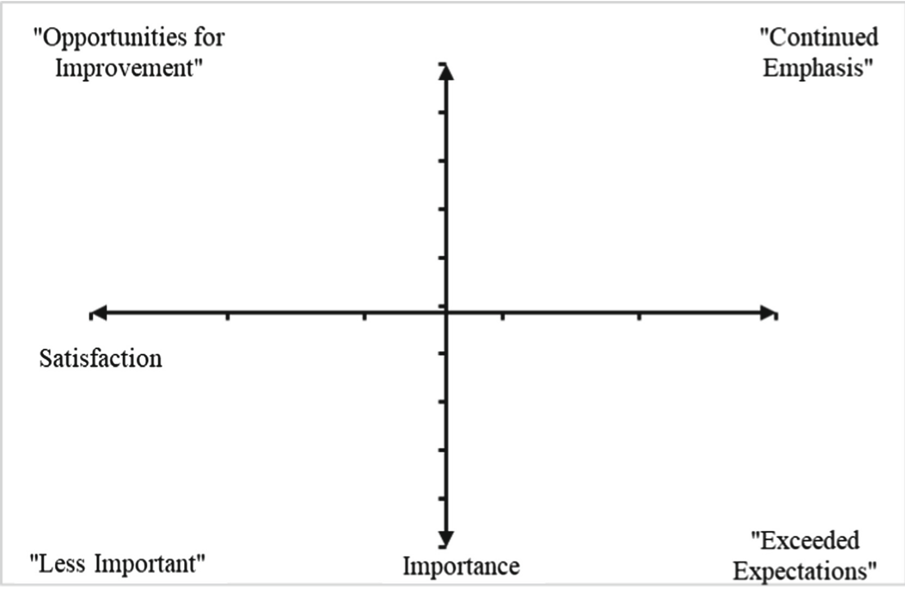

Fig. 2. Example importance-satisfaction matrix.

4 Results and Discussion

In this chapter, the distribution of the data gathered were first discussed, followed by office design and other factors affecting job satisfaction. Lastly, importance satisfaction analysis was presented and summarized.

4.1 Distribution of Data

Just like the required number of samples needed for the study, a total of 174 government employees in the Laguna Provincial Capitol served as respondents of the study (i.e. 100% response rate was achieved). The required number of samples per office type were also met.

In dispersing the samples gathered across departments, the number of samples gathered for each department was based on the ratio of the population for each department to the total population. For instance, considering that the accounting and treasury departments have the largest number of employees, large number of samples came from them. On the other hand, since moral and woman department has the smallest population, only two samples were gathered from this department.

Considering their age, majority are 36–45 years old. Also, two-thirds of the respondents are female. With respect to their civil status, most of them are married. About three-fourths have Bachelor's degree. Lastly, 45% of the respondents work for the Laguna Provincial Capitol for 16–25 years.

In terms of nature of work, most of the respondents are general office clerks (38%) and administrative assistants/secretaries (26%). Only 2%, on the other hand, are receptionists.

4.2 Factors Affecting Job Satisfaction

The respondents were asked to rank 13 factors that affect job satisfaction from 1 to 13 (1 having the biggest contribution to job satisfaction and 13 having the smallest contribution). The sum of the ranks of the respondents per factor was considered in determining the overall rank of the factors.

On the average, the employees believed that their relationship with their immediate supervisor contributes the most to their job satisfaction, while their flexibility, or their ability to choose their own schedule, contributes the least. On the other hand, office design placed 8 in the final ranking of the factors.

4.3 Importance-Satisfaction Analysis

The importance-satisfaction analysis was done first by considering all the respondents of the study, regardless of which office type they occupy. Afterwards, corresponding analyses for every office type were performed. The importance-satisfaction matrix

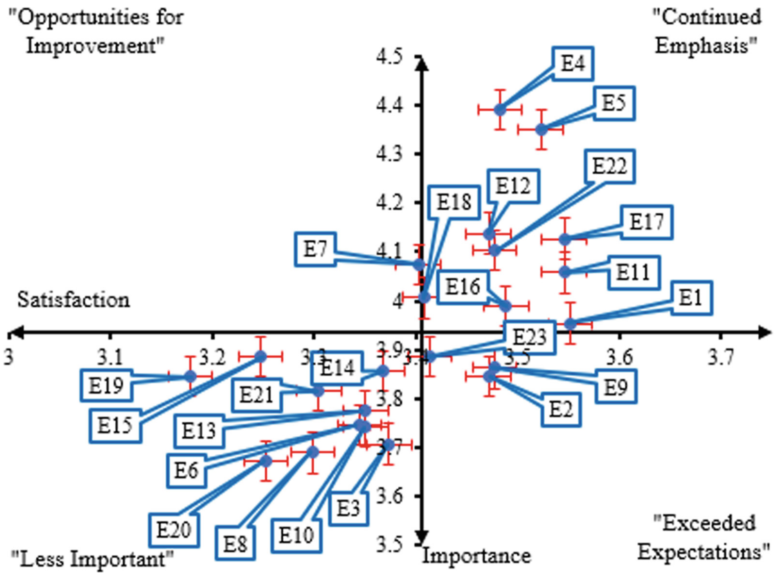

Fig. 3. Importance-satisfaction matrix considering all the respondents of the study.

considering all respondents of the study was shown on Fig. 3 as example. The results of the importance-satisfaction analyses conducted are summarized in the appendix section of this paper. It reveals what quadrant did each element of office design fall for each office type, and in general.

Those elements that fall on the first quadrant met the expectations of employees, as they relatively have high importance and satisfaction ratings. Those that belong to the second quadrant have relatively high importance rating but low satisfaction rating; thus, there is a need to improve these elements. Elements belonging to the third quadrant are considered as less important, as they relatively have low importance and satisfaction ratings. Lastly, those that fall on the fourth quadrant exceed the expectations of the employees, as they relatively have low importance rating but high satisfaction rating.

5 Summary and Conclusion

Office design is considerably vital in the everyday lives of the government employees of the Laguna Provincial Capitol. With this, it is important to ensure that these employees are satisfied with their office design. In this study, numerous tools were used in determining how the current office design in the Laguna Provincial Capitol impacts the satisfaction of its occupants. Different office types present inside the said institution were first recognized. Seven office types were identified as follows: individual office, shared room, small open plan, medium open plan, large open plan, cubicle, and half partition.

Importance-satisfaction analyses were performed to determine what office design elements should be given priority per office type. Eight matrices were generated, one for the general office and one for each of the seven different types of offices.

Every type of office has its own set of office design elements that need management's attention. Again, the management should focus on the office design elements that fall on the second quadrant (Opportunities for Improvement), as these elements have relatively high importance for the employees; however, satisfaction of employees on these elements is relatively low. By doing so, satisfaction of employees on the design of their office will significantly improve.

6 Recommendation

General recommendations in this study were first provided, then corresponding recommendations for each type of office were specified. Generally, the management should focus on improving the overall environment inside the workplace of the government employees of the Laguna Provincial Capitol.

Employees should feel comfortable and relaxed while working inside their office. For instance, maintaining a clean and attractive office environment, helps employees feel comfortable while doing their tasks in the workplace.

For the individual offices, the management should focus on improving the following: functionality of office furniture, office furniture ergonomics, overall environment in the workplace, access to interaction and communication spaces, ability of workstation to support work and daily needs, comfort in workstation, layout of workstation, and size of workstation. To enhance the individual office occupants access to interaction and communication spaces, an office relocation may be needed, to make the interaction and communication spaces accessible to the employees. However, given the current layout of the offices, this may take some time to be achieved. The management should also prioritize improving the workstation of the individual office occupants (ability of the workstation to support the daily needs, comfort felt by the occupant in the workstation, size of the workstation, and layout of the workstation. For example, in improving the ability of the workstation to support the daily needs, frequently used office supplies should always be available to the employees when in need. But it is actually up to the employees on how they organize their workstations. They may classify the items they use as primary (items a worker uses regularly), secondary (items that are used less often), and reference (items that are rarely used), then place the primary items as near to them as possible to minimize reach. Some individual office occupants also need larger workstations, since their current workstation are not sufficient to support their daily needs.

For shared room offices, the management should focus on improving the functionality of office equipment. As observed, most of the equipment they commonly use, especially printers and photocopying machines, do not function well, as they frequently undergo paper jams. Thus, repairs or replacement of these units are needed. For small open plan offices, aside from the overall environment in the workplace, acoustic conditions should also be paid attention to. Thus, the management should consider investing on acoustically absorptive materials such as carpet and acoustic wall panels to minimize the noise levels inside small open plan offices. For medium open plan offices, acoustic conditions should also be improved. Also, the indoor air quality inside these offices should be improved. Lack of ventilation systems inside medium open plan offices, may be the primary reason why employees rated their indoor air quality relatively low. Given that there are 10-24 occupants inside these offices, aside from air conditioning units, there should also be mechanical ventilation (e.g. electric fans) inside, in order to circumvent inadequate supply of fresh air. Also, air purifiers and plants are needed to be installed inside these offices to maintain a clean and fresh air.

For large open plan offices, aside from overall environment in the workplace, and indoor air quality, the management should focus on improving the size of workstation of employees. Voluminous working files and documents are just stockpiled on top of their desks, indicating that their workstations are not able to accommodate them properly. The management should either provide larger workstations (only if necessary) or larger storage areas, so that large open plan office occupants can work with ease.

For cubicle offices, access to office equipment and workplace layout should be improved. When a visual inspection was done, it was observed that office equipment commonly used by the cubicle office occupants, such as printer and photocopying machines are located outside the cubicle), which make the employees travel at far distances just to have access to such equipment. Thus, the office equipment used by cubicle office occupants should be relocated within the cubicle, or close to the cubicle where the occupant is situated. Moreover, there is a need to adjust, rearrange, and reorganize units inside cubicle offices so as to comply with the layout preferred by the employees.

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Appendix: Importance-Satisfaction Matrix Summary

OFFICE DESIGN ELEMENT	OFFICE TYPE							
	General	Individual	Shared room	Small open plan	Medium open plan	Large open plan	Cubicle	Half partition
Functionality of office furniture	I	II	IV	IV	IV	I	IV	I
Office furniture ergonomics	IV	II	IV	III	IV	IV	IV	IV
Furniture flexibility	III	III	IV	III	III	IV	III	III
Functionality of office equipment	I	I	II	I	I	I	I	I
Access to office equipment	I	I	I	I	I	I	II	I
Workplace layout	III	III	IV	III	III	III	II	IV
Overall environment in the workplace	II	II	I	II	I	II	I	I
Access to breakout or social spaces	III	III	III	III	III	III	III	III
Access to interaction and communication spaces	IV	II	III	III	IV	IV	III	I
Access to storage facilities	III	III	III	III	IV	IV	III	III
Ability of workstation to support work and daily needs	I	II	III	I	I	IV	I	I
Comfort in workstation	I	II	IV	I	I	I	I	I
Layout of workstation	III	II	IV	III	III	III	IV	III
Size of workstation	III	II	III	IV	IV	II	IV	III
Acoustic conditions	III	III	I	II	II	III	III	III
Thermal conditions	I	I	I	I	I	I	III	IV
Lighting conditions	I	I	I	I	I	I	III	I
Indoor air quality	I	I	I	I	II	II	III	I
Ability to stop unwanted background noise	III	II	I	III	III	III	IV	III
Ability to avoid visual disturbance	III	IV	I	III	III	III	IV	III
Access to quiet spaces	III	IV	I	III	III	III	IV	III
Ability to concentrate	I	I	I	I	I	I	I	I
Overall privacy	IV	I	I	I	III	I	I	IV

**Quadrants: I-Continued Emphasis, II- Opportunities for Improvement, III- Less Important, IV- Exceeded Expectations*

References

1. Sageer, A., Rafat, S., Agarwal, P.: Identification of variables affecting employee satisfaction and their impact on the organization. J. Bus. Manag. **5**(1), 32–39 (2012)
2. Danielsson, C.B., Bodin, L.: Difference in satisfaction with office environment among employees in different office types. J. Archit. Plann. Res. **26**(3), 241–256 (2009)
3. Tanjeen, E.: A study on factors affecting job satisfaction of telecommunication industries in Bangladesh. J. Bus. Manag. **8**(6), 80–86 (2013)
4. Vrabie, A.: 10 psychological job satisfaction factors that really matter (2014). http://blog.sandglaz.com/10-psychological-job-satisfaction-factors-that-really-matter/. Accessed 9 Sept 2017
5. Commission For Architecture and The Built Environment, The British Council for Offices. British business leaders urged to consider the impact of design, as report shows it can affect workforce performance by up to 11percent [Press release] (2005). http://www.bco.org.uk/uploaded/cabe_bco_final.doc.doc6. Accessed 4 Sept 2017. National Center for Biotechnology Information. http://www.ncbi.nlm.nih.gov
6. Juhari, A.: The impact of office design towards employee productivity: a case study among the employee in BFM media sdn bhd (Unpublished Master's thesis). Universiti Teknologi MARA (2016)
7. Waqas, A., Bashir, U., Sattar, M.F., Abdullah, H.M., Hussain, I., Anjum, W., Arshad, R.: Factors influencing job satisfaction and its impact on job loyalty. Int. J. Learn. Dev. **4**(2), 141–161 (2014). https://doi.org/10.5296/ijld.v4i2.6095
8. Ellickson, M.C.: Determinants of job satisfaction of municipal government employees. Public Pers. Manag. **31**(3), 343–358 (2002). https://search.proquest.com/docview/215944023?accountid=173015
9. De Been, I., Beijer, M.: The influence of office type on satisfaction and perceived productivity Support. J. Facil. Manag. **12**(2), 142–157 (2014). https://doi.org/10.1108/JFM-02-2013-00113
10. Salvendy, G. (ed.): Handbook of Human Factors and Ergonomics. Wiley, Baltimore (2012)
11. Romyn, J.: 4 types of open-plan office: which one works for you? (2016). Accessed 4 Sept 2017. https://www.realcommercial.com.au/news/4-types-open-plan-office-one-works
12. Danielsson, C.B., Bodin, L.: Office type in relation to health, well-being, and job satisfaction among employees. Environ. Behav. **40**(5), 636 (2008). https://search.proquest.com/docview/200881222?accountid=173015
13. Fan, K.: Survey and analysis of employee satisfaction (Order No. 10334456). ProQuest Dissertations & Theses Global. (1869126675) (2010). https://search.proquest.com/docview/1869126675?accountid=173015
14. Rane, D.: Employee job satisfaction: an essence of organization. HRM Rev. **11**(7), 10–16 (2011). https://pdfs.semanticscholar.org/defa/659c3154666b03c3c7d7399c0b794ce7edef.pdf
15. Zafir, M.M., Durrishah, I., Mat Rebi, A.R.: Ergonomics design on the work stress outcomes. Jurnal Kemanusiaan Bil **9**, 1–12 (2007)

Macroergonomics Factors Generating Work Time Losses in Interpretation of Grey Systems Theory

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Abstract. This paper presents the causes of work time losses related to the human aspect as a result of human behavior which is a consequence of factors affecting it. It was shown that the Grey Systems Theory (GST) can also be applied to the analysis of work time losses in a multiagent production system The decision to choose GST for this purpose was also justified. The aim of the publication is to show that the Grey Systems Theory gives the possibilities of analyzing data that is incomplete, uncertain or too few and this type of information occur regarding work time losses in the multiagent production system.

Keywords: Macroergonomics · Work time losses · Grey Systems

1 Introduction

Work time losses are unwanted phenomenon in each enterprise. It causes disorder in working time process, net output reduction which makes smaller profit, impracticability of production principles to complete as scheduled and failed contracts. Therefore, enterprise management aspires to achieve work time losses as small as possible. It is necessary to identify their source in first step, and next to decide how to reduce them or completely eliminate if it is possible.

Among causes determining work time losses, dominating factors those, which represent macroergonomics category.

Literature [6] sets apart ergonomics of first, second and third generation. Ergonomics of first generation (human machine interface technology) was orientated on perception phenomenon researches, anthropology issue, also analysis and design human – machine systems. Expanded analysis and researches on human – computer interaction and focused on human's cognitive and decision - making purposes, became the beginning of ergonomics of second generation (user system interface technology). Natural consequence of ergonomic analysis and researches expanding was orientation on complex processes. The initial phase the range of diagnostic and design activities in reference to multielemental manufacturing systems was limited to so-called unique activities and working teams. It is said today about macroergonomics design and diagnostic [7, 13] that means ergonomic of third generation with reference to manufacturing process: organization – machine

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interface technology. Macroergonomics approach is dedicated to multielemental objects so organization treated as a inseparable part of external environment [13].

The scientific researches' subjects of macroergonomics are human – centrally orientated so-called social engineering systems. They involve organized communities, compound with people and technology creation, which all together realize manufacturing and subordinate working process [12]. By reason of that the determinants of work time losses are possible to divide in two groups: human aspects' and technology (technical) aspects' reasons.

2 Technical Determinants of Work Time Losses

The most frequent technical causes of work time losses are machines' mechanical breakdowns related with cracks, wear out or became blunt machines' tools which are the most operated and exposed on working in adverse conditions (Fig. 1). Usually there are trivialities breakdowns last for several minutes, but frequently of their appearance causes substantial work time losses in long term of machines' utilization. The paper [15] presents an analysis of machines' operators working time utilization in one-week period. Weekly working time standard is used in a bit above 70%, however work time losses reach nearly 30% including over 13% of "other work time losses" (Fig. 2).

Machine's resetting cause significant work time losses in production process. They do not happen very frequently, but the real time assigns to machine's tools replacement is too long. Unnormalized periods of preparation and finishing the process (t_{pz}) make machine's resetting a task realized according to availability of disposers, hierarchy of task priorities or gender of products. Resetting machine on technologically similar items, which requires to set just one or two machining parameters without replacing machine's tools is usually takes several hours. It is an obvious working time lost. Sometimes during a resetting the line's operator is being transferred into another post. The line is quickly and efficiently prepared for a new type of element but the operator does not return to his work-station until the end of his shift.

Research results show [15], that size of the product and its processing parameters affect rising production time losses. All machines in production line have a determined scope of optimal work, which guarantees a relatively stable process of production and provides precisely defined technological parameters. Processing bigger elements, which reach limits of optimal work might cause instability of the machine and necessity of constant adjustment of the machine. The processing velocity is also important. Shortening of unitary time limits in individual types of production has caused more mechanical failures of machines and exigency of more frequent controlling of product's parameters and correcting and regulating processing parameters of machines. Resetting machines from the production line into a technologically similar type or preparing for processing elements of suchlike processing parameters hasn't cause any difficulties. All problems resulted from resetting machines from a small type into large one or vice versa. Big difference between products' sizes and their processing parameters caused significant work time losses by every initiation of new type of production, especially because of frequent regulation of machines. Summarizing, we might state, that work time losses in production processes are result of function of reliability of machines and their operators. Machines' and devices' failures are caused by their wear, exploitation and service errors, use of material and by disregarding rules of technology and production management.

Efficiency of line : 1	Total shift hours				
	120	120	120	64	120
Weeks	49	50	51	1	2
Actual output	61 930	67 628	69 938	19 954	57 235
Official break	0	0	0	0	0
Mech. Breakdowns	4 714	5 036	3 375	8 985	14 932
Elektr. Breakdowns	214	536	321	0	1 159
No people	2 571	0	0	0	9 000
No tools	0	0	0	0	0
Resetting	0	0	0	5 143	0
No material	4 714	1 179	1 554	5 357	3 136
Others	2 999	2 765	1 955	4 509	12 720
Total	77 143	77 143	77 143	43 948	98 182

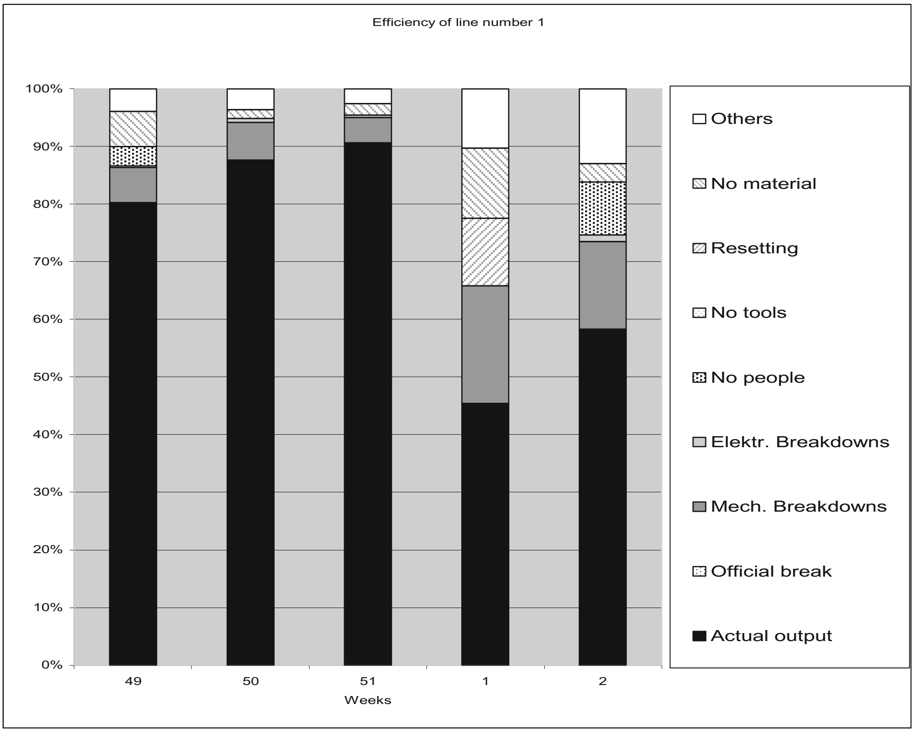

Fig. 1. Bar graph of production line's utilization. Source: research materials from sources of a factory producing machines parts

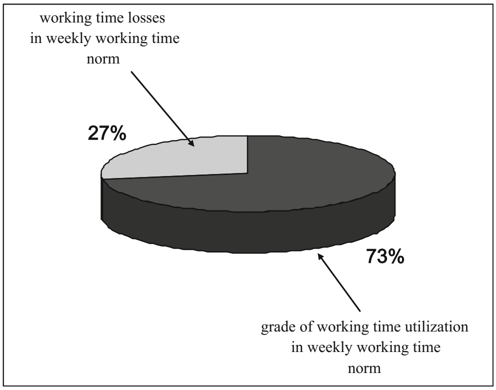

Fig. 2. Analysis of machines' operators working time utilization in one week period. Source: personal elaboration.

3 Analysis of Humanization Causes of Work Time Losses with Grey Systems Theory

Among factors conducing work time losses there is a group, which can't be measured by traditional, accurate methods. Presented research illustrate, that a part work time losses appears in circumstances difficult to explain. Their reason are not possible to define by analyzing work time losses charts filled by machines' operators of examined enterprise every day.

Work time losses are caused by the human factor, although we do not know why. Treating man as reason of work time losses favors considering aspects of indefiniteness, inaccuracy, uncertainty and inability to obtain measurable data.

Dealing with this type of information, to study work time losses, the Grey Systems Theory (GST) can be applied. Its creator is a Chinese professor at Huazhong University-Juo-Long Deng. He presented this theory in 1982 in a publication [4] Since then, it has gradually begun to complement three approaches: statistical, fuzzy and coarse, used for uncertain systems. Unlike white systems (*whitebox*), that are known about everything and black systems *(blackbox)* that are missing any data, grey systems (*greybox*) are characterized by a limited amount of information about them [1, 8, 16].

The greyness of complex systems can be divided into at least two categories: information incompleteness and uncertainty of impacts. Usually observations (measurements, market research results, opinions, etc.) are few, so the information about the system's behavior is also incomplete. The theory of grey systems includes the following four possible systems with incomplete information: [4, 5]

- information about individual elements/system parameters is incomplete,
- information on system boundaries is incomplete,
- information about changes/system dynamics (surroundings/environment) is incomplete.

In addition, on the basis of such incomplete and uncertain information, it is often necessary to evaluate the operation of the system, forecast its behavior and make various functional decisions - operational and strategic [3].

In this publication, the system of work time losses considered can be treated as a grey complex system due to having incomplete, uncertain and few information on it. Thanks to the use of grey systems theory, it will be possible to create a reliable model of a grey work system, despite the mentioned information gaps, to predict its behavior and make various current decisions on this basis [3].

A work system, which is a complex system, can have many areas of impact on the environment or from the work environment, also from neighboring - cooperating systems. Sometimes it is even difficult to distinguish whether it is a factor affecting this system or its reaction. Complex systems can therefore have many inputs that stimulate our system, as well as many outputs that give the system reaction to the environment. From the modeling point of view, these will be multi-input and multi-input systems, and their observations will give us a set of behavioral vectors and vectors of influence factors. These may be, for example, two vectors, as it is shown below, but there may also be more if we are interested in many behaviors and factors in the system [10]:

$$\boldsymbol{X}_i = (x_i(1), x_i(2), \ldots, x_i(n)) \quad \boldsymbol{X}_j = \left(x_j(1), x_j(1), \ldots, x_j(n)\right) \tag{1}$$

There are vectors of the same length, measured at the time of observation $k = 1,\ldots, n$.

Without precise information about the written down observation vectors, one can not be sure whether they are the output or input of the system. First it is necessary to research the mutual similarity between X_i and X_j vectors. In the Grey Systems Theory of, this similarity research process is called Gray Incidence (Relation) Analysis. – **GRA**. This analysis makes it possible to determine the interrelationships between various factors and their impact on the tested system.

The analysis of mutual relations between observation vectors gives us information about our system at a given moment of time. However, development tendencies that are inherent in our system may be equally important. Often, we want to know what is the development trend of a given observation vector, that is, we want to make a forecast of its future behavior. For this purpose you need to work out a model of the grey system. With this model, you can get a forecast of the possible future behavior of the system [3].

4 Research

4.1 Research Description

The research was conducted in machine parts manufacturing company in Poland. The sample consisted of 30 respondents who are employees of the Production Department of this company. The research used a questionnaire consisting of 30 questions regarding the causes of work time losses caused by the human factor. Answers to closed questions could be selected from a 6-point scale, where 1 means the lowest grade (weight), and the sixth - the highest. The data received from respondents enabled, among others, to indicate the most important causes of work time losses caused by human fault. For the analysis of data, 5 humanizing causes of work time losses were selected, most often indicated by the examined persons.

The GRA method – *grey incidence* (*relation*) *analysis* was used for data analysis. Its description can be found in publications [3, 8, 11]. It allows for inference based on data that is incomplete, uncertain and few. The aim of the analysis is to create a reliable model of the grey work system, so as to predict its behavior and make current decisions regarding the elimination or possible prevention of the occurrence of causes of work time losses in the future.

4.2 Analysis of the Causes of Work Time Losses in Concepts of Grey Systems Theory

With the use of the GRA method, which was used to analyze the data, one can determine the absolute (total) similarity incidence (*absolute degree of grey incidence*) of observed factors of work time losses and characteristics of the work system. The procedure for analyzing the collected data was carried out in the sequence of seven steps and presented below [2, 3, 14]:

Step 1. The first step is to obtain a system observation vector made at successive moments of time and to make sure that it does not contain negative values. They contain information about system characteristics (X_0) and system behavior factors (X_1, X_2,…, X_k). The number of system behavior factors depends on the number of observed variables. Each vector contains information about a given variable obtained from a given number of respondents. The general system observation vector has the following form:

$$\begin{aligned} X_{(0)} &= \left\{x_{(0)}(1), x_{(0)}(2), \ldots x_{(0)}(n)\right\} \\ X_{(\mathrm{k})} &= \left\{x_{(\mathrm{k})}(1),\, x_{(\mathrm{k})}(2), \ldots x_{(\mathrm{k})}(n)\right\} \end{aligned} \tag{2}$$

where:

k – number of observed variables (factors of system behavior, which are in this case the reasons for work time losses),

n – the number of respondents.

The minimum number of observations which from you can start creating the model is 4 [3].

In the presented analysis, the data was obtained from 30 surveyed people. The individual vectors describe the system and its behavior as shown below:

X_0 – work system in the aspect of work time losses
X_0 = (6, 5, 6, 4, 6, 5, 5, 4, 6, 6, 5, 3, 4, 6, 4, 5, 5, 5, 6, 6, 6, 5, 6, 5, 5, 3, 6, 4, 6, 5)
X_1 – bad conditions of the physical working environment
X_1 = (4, 4, 3, 6, 3, 5, 5, 4, 6, 5, 6, 5, 4, 6, 4, 2, 5, 4, 5, 3, 5, 5, 6, 5, 4, 5, 6, 3, 5, 6)
X_2 – work and life stress
X_2 = (6, 5, 5, 4, 5, 5, 6, 4, 6, 5, 5, 6, 6, 5, 4, 4, 6, 6, 6, 5, 6, 5, 5, 6, 6, 5, 5, 4, 4, 6)
X_3 – work overload
X_3 = (4, 4, 5, 3, 3, 6, 5, 4, 5, 6, 4, 5, 3, 5, 6, 4, 5, 5, 4, 5, 5, 6, 4, 5, 4, 4, 6, 5, 3, 5)
X_4 – bad mood

X_4 = (5, 5, 4, 3, 6, 6, 6, 5, 6, 4, 4, 5, 6, 2, 6, 4, 3, 4, 5, 5, 6, 3, 3, 5, 4, 6, 4, 5, 2, 4)
X_5 – lack of development opportunities
X_5 = (2, 4, 3, 4, 5, 4, 2, 3, 5, 4, 2, 1, 4, 6, 5, 5, 4, 3, 2, 3, 4, 3, 1, 3, 3, 2, 4, 2, 3, 1).

Step 2. In the second step, an accumulation operation is performed on the original observation vector, smoothing random disruptions and highlighting the evolutionary tendency of the gray system behavior. This is obtained by successive subtotals:

$$x^{(1)}(k) = \sum_{i=1}^{k} x^{(0)}(i), \quad k = 1, 2, \ldots, n \tag{3}$$

creating a new, smoothed vector of observation

$$x^{(1)} = \left\{x^{(1)}(1), x^{(1)}(2), \ldots x^{(1)}(n)\right\} \tag{4}$$

with an obvious initial condition: $x^{(1)}(1) = x^{(0)}(1)$.

Step 3. It must be assumed that the smoothed vector $\boldsymbol{x}^{(1)}$ it is a function of time t and is the solution to the first order differential equation,

$$\frac{dx^{(1)}(t)}{dt} + ax^{(1)}(t) = u \tag{5}$$

with development coefficient and the coefficient of extortion u. They will be later determined according to the smoothed vector data $\boldsymbol{x}^{(1)}$.

Step 4. The solution of this differential equation for unit bound of variable $t = 1$ has the following form:

$$\hat{x}^{(1)}(k+1) = \left[x^{(0)}(1) - \frac{u}{a}\right] \exp(-ak) + \frac{u}{a} \tag{6}$$

where the peak on the smoothed variable $\hat{x}^{(1)}$ means its forecast with still unknown coefficients a and u that will be determined in the next step.

Step 5. In order to determine these coefficients, the differential Eq. (5) will be converted into a differential equations system:

$$\begin{aligned} x^{(1)}(k+1) - x^{(1)}(k) + ax^{(1)}(k) = u \\ x^{(1)}(k+1) - x^{(1)}(k) + ax^{(1)}(k+1) = u \end{aligned} \tag{7}$$

which after the transformations will give us a system of equations;

$$x^{(1)}(k+1) - x^{(1)}(k) = -\frac{a}{2}\left[x^{(1)}(k) + x^{(1)}(k+1)\right] + u, \quad \mathrm{k} = 1, \ldots, \mathrm{n} \tag{8}$$

Step 6. After developing the Eq. (8) for successive k = 1, 2,… and using the primary observation vector $\boldsymbol{x}(0)$ we'll get a matrix equation used to determine the coefficients a i u [2]:

$$[a, u]^T = (B^T B)^{-1} B^T \mathrm{Y} \tag{9}$$

where vector $\boldsymbol{Y} = \left[x^0(2), x^0(2), \ldots, x^0(n)\right]^T\Big]$, and the matrix for the implementation of explanatory variables is given in the following form [2]:

$$B = \left[\left[\begin{array}{cc} -\left[x^{(1)}(1) + x^{(1)}(2)\right]/2 & 1 \\ -\left[x^{(1)}(2) + x^{(1)}(3)\right]/2 & 1 \\ \vdots & \vdots \\ -\left[x^{(1)}(n-1) + x^{(1)}(n)\right]/2 & 1 \end{array}\right]\right] \tag{10}$$

Step 7. Knowing the coefficients a i u, one can think about returning to the primary observation vector and to its prediction created on the basis of the already known model of the grey system. To do this, the reverse operation of the previous partial summation should be used, that is, subtracting successive forecasts of smoothed vectors $x^{(1)}(k)$ from each other [3]:

$$\hat{x}^{(0)}(k+1) = \hat{x}^{(1)}(k+1) - \hat{x}^{(1)}(k) \tag{11}$$

Returning in this way to the original variables and solutions, the model of behavior of the gray system and its forecast in the form were finally obtained [3]:

$$\hat{x}^{(0)}(k+1) = \left[x^{(0)}(1) - \frac{u}{a}\right]\left(e^{-ak} - e^{-a(k-1}\right), \quad k = 2, 3, \ldots, n \tag{12}$$

with a forecast error vector [3]:

$$\varepsilon = x^{(0)}(k) - \hat{x}^{(1)}(k) \tag{13}$$

In this way, the process of creating the simplest model of the grey system (GS) is presented, according to the concept of J.-L. Dengue, called GM (1,1), which means a grey first-order model with one forcing input in the form of a parameter u. It is a grey system model most often used for the analysis and prediction of system behavior, from scientific and technical to economic and social one.

4.3 Analysis of the Similarity of Observation Vectors of Grey Systems (GRA)

As shown in the relation (1), here we have two images of the behavior of the gray system – vectors [3]:

$$X_i = [x_i(1), x_i(2), \ldots, x_i(n)]; X_j = \left[x_j(1), x_j(2), \ldots, x_j(n)\right] \tag{14}$$

the same length, measured at the time of observation: k = 1,…, n.

It is necessary to calculate the so-called reflection of observation vectors by resetting the initial values of vectors. This operation allows smoothening random disruptions and emphasizes the evolutionary tendency of the grey system behavior. This operation is carried out according to the following formula [3]:

$$\begin{aligned} X_i^0 &= \left[x_{(i)}(1) - x_{(i)}(1),\, x_{(i)}(2) - x_{(i)}(1), \ldots, x_{(i)}(n) - x_{(i)}(1)\right] \\ X_j^0 &= \left[x_{(j)}(1) - x_{(j)}(1),\, x_{(j)}(2) - x_{(j)}(1), \ldots, x_{(j)}(n) - x_{(j)}(1)\right] \end{aligned} \tag{15}$$

When the data from the conducted research has been analyzed, the following values for the reflection of the observation vector were received:

X_0^0 = [0, −1, 0, −2, 0, −1, −1, −2, 0, 0, −1, −3, −2, 0, −2, −1, −1, −1, 0, 0, 0, −1, 0, −1, −1, −3, 0, −2, 0, −1]
X_1^0 = [0, 0, −1, 2, −1, 1, 1, 0, 2, 1, 2, 1, 0, 2, 0, −2, 1, 0, 1, −1, 1, 1, 2, 1, 0, 1, 2, −1, 1, 2]
X_2^0 = [0, −1, −1, −2, −1, −1, 0, −2, 0, −1, −1, 0, 0, −1, −2, −2, 0, 0, 0, −1, 0, −1, −1, 0, 0, −1, −1, −2, −2, 0]
X_3^0 = [0, 0, 1, −1, −1, 2, 1, 0, 1, 2, 0, 1, −1, 1, 2, 0, 1, 1, 0, 1, 1, 2, 0, 1, 0, 0, 2, 1, −1, 1]
X_4^0 = [0, 0, −1, −2, 1, 1, 1, 0, 1, −1, −1, 0, 1, −3, 1, −1, −2, −1, 0, 0, 1, −2, −2, 0, −1, 1, −1, 0, −3, −1]
X_5^0 = [0, 2, 1, 2, 3, 2, 0, 1, 3, 2, 0, −1, 2, 4, 3, 3, 2, 1, 0, 1, 2, 1, −1, 1, 1, 0, 2, 0, 1, −1]

Next, the behavior measures [3] of the above vectors should be calculated by adding and subtracting their values [9]:

$$s_i = \sum_i^n X_i^0 \tag{16}$$

$$s_i - s_j = \sum_i^n X_i^0 - \sum_i^n X_j^0 \tag{17}$$

The next step is to calculate the absolute (total) degree of similarity between observation vectors X_0 i X_1, X_2, X_3, X_4, X_5, i.e. values of the similarity coefficient ε (eng. *the absolute degree of grey incidence*) [9]:

$$\varepsilon_{ij} = \frac{1 + |s_i| + |s_j|}{1 + |s_i| + |s_j| + |s_i - s_j|} \tag{18}$$

This factor is characterized by the following properties, very important for the system assessment [3]:

(1) $0 < \varepsilon_{ij} \leq 1$;
(2) ε_{ij} is related only to the geometrical shape of the vectors $\boldsymbol{X_i}$ and $\boldsymbol{X_j}$, it is not related to their spatial arrangement;
(3) every two vectors are even minimally related, so ε_{ij} does not take the value zero;
(4) the more the vectors of observation are related (similar), the higher is the value ε_{ij};
(5) if the vectors of observation are parallel or fluctuate around each other, value ε_{ij} the value is equal to or close to 1;
(6) if one of the vectors changes, it also changes ε_{ij};
(7) if the length of the vectors changes, it also changes ε_{ij};
(8) Finally, there is the identity relation $(\varepsilon_{ii} = \varepsilon_{jj} = 1)$ and symmetry $(\varepsilon_{ij} = \varepsilon_{ji})$.

It seems that with this measure we can evaluate the similarity of the behavior of a pair of vectors, and to evaluate their degree of connection, if we know that one of them represents a factor affecting the grey system, and the other - system reactions.

The use of formulas (16–18) to analyze the results of the conducted research is shown below:

$$|s_0| = \left| \sum_{k=2}^{30} x_0^0(k) + \frac{1}{2} x_0^0(30) \right|$$

$$|s_1| = \left| \sum_{k=2}^{30} x_i^0(k) + \frac{1}{2} x_i^0(30) \right|$$

$$|s_0 - s_1| = \left| \sum_{k=1}^{30} \left[x_0^0(k) - x_i^0(k) \right] + \frac{1}{2} \left[x_0^0(30) - x_i^0(30) \right] \right| \tag{19}$$

$$\varepsilon_{0i} = \frac{1 + |s_0| + |s_i|}{1 + |s_0| + |s_i| + |s_0 - s_i|} \tag{20}$$

Table 1 shows the values of the similarity coefficient for the observed system characteristics (X_0) with the behavioral factors of the system $(X_1, X_2, X_3, X_4, X_5)$ [based on 10].

Table 1. Values of similarity (of impact) ε_{0i}

Factors of the work system in the aspect of work time losses	The value of the influence factor of system factors on X_0
*X*1 – bad conditions of the physical working environment	ε_{01} = 0,627556
*X*2 – work and life stress	ε_{02} = 0,683723
*X*3 – work overload	ε_{03} = 0,671254
*X*4 – bad mood	ε_{04} = 0,659213
*X*5 – lack of development opportunities	ε_{05} = 0,613269

After determination the value of the impact coefficient of system factors, the order of influence of the tested system factors (causes of X of the work time losses) on the characteristics of the work system is determined. Order of relationship strength X_1, X_2, X_3, X_4, X_5 z X_0 looks like is shown below:

$$\mathcal{E}_{02} > \mathcal{E}_{03} > \mathcal{E}_{04} > \mathcal{E}_{01} > \mathcal{E}_{05} \tag{21}$$

From the obtained result, it can be concluded that among the factors listed above the stress of work and life has the greatest impact on the creation of work time losses, and work overload in the second place. In the least extent, work losses result from the lack of development opportunities.

The above analysis of the work system in the aspect of work time losses could of course be extended by a greater number of reasons determining the work time losses.

5 Summary

Work time losses come not only from wear of machines, exploitation and service errors, use of material or disregarding rules of technology and production management. They also appear because of man's behavior. We must deeply analyze human physical and psychological aspects to recognize reasons of such problems. We should analyze all factors affecting man, its behavior, attitude and reactions, so we might solve the riddle of work time losses' origin. Presented question is important from the technological point of view, but also from the psychological side. It is crucial to study this problem from the macroergonomics side, having interactions between man, technology and their work environment in the center of its interest.

The use of deterministic methods and probabilistic rules for this purpose is sometimes ineffective and unreliable. In this situation, the right solution is using the Grey Systems Theory in this area, because on the basis of incomplete information about individual elements of the given system of work in the enterprise with special regard to work time losses or changes in this system, it will be possible to gather about the existing work time losses, define the desirable state and contribute to making a decision to eliminate or at least partially reduce their causes. An additional advantage of the Grey Set Theory is the minimum number of observations, which is four.

References

1. Andrew, A.M.: Why the world is grey. Grey Syst. Theory Appl. **1**(2), 112–116 (2011)
2. Barczak, S.: Zastosowanie teorii szarych systemów do przewidywania przyszłych ofert składanych na aukcjach pierwszej ceny poprzez pryzmat modelu szarego systemu, Zeszyty Naukowe Akademii Ekonomicznej w Katowicach, pp. 1–18 (2011)
3. Cempel, C.: Teoria szarych systemów – nowa metodologia analizy i oceny złożonych systemów. Przegląd możliwości. Zeszyty Naukowe Politechniki Poznańskiej, seria Organizacja i Zarządzanie, nr 63, pp. 9–20 (2014)
4. Deng, J.-L.: Control Problems of Grey Systems, Syst. Control Lett. **1**(5), 288–294 (1982)
5. Deng, J.-L.: Introduction to grey system theory. J. Grey Syst. **1**(1), 1–24 (1989)

6. Hendrick, H.W.: Macroergonomics. A concept whose time has come. Hum. Factors Soc. Bull. **30**, 2 (1987)
7. Jasiak, A.: Kryterium czynnika ludzkiego w projektowaniu systemów wytwarzania, Wydawnictwo Politechniki Poznańskiej (1993)
8. Liu, S.F., Lin, Y.: Grey Systems – Theory and Applications, Springer, Berlin, 379 p. (2010)
9. Liu, S., Lin, Y.: Grey Information. Theory and Practical Applications. Springer, London (2006)
10. Liu, S.F., Forrest, J., Yang, Y.: A brief introduction to grey systems theory. Grey Syst. Theory Appl. **2**(2), 89–104 (2012)
11. Mierzwiak, R., Więcek-Janka, E.: The analysis of successors' competencies in family enterprises with the use of grey system theory. Grey Syst. Theory Appl. **5**(3) (2015)
12. Pacholski, L.: Makroergonomiczne strategie relacyjne. In: Marcinkowski, J.S., Horst, W.M. (eds.) Aktualne problemy Bezpieczeństwa pracy i ergonomii. Edukacja i badania, Wydawnictwo Instytutu Inżynierii Zarządzania Politechniki Poznańskiej, Poznań, p. 270 (2007)
13. Pacholski, L., Jasiak, A.: Application of system methodologies to macroergonomic diagnosing. In: Kumar, S. (ed.) Advances in Industrial Ergonomics and Safety IV (1992)
14. Ragin-Skorecka, K.: Teoria systemów szarych w badaniach nad tożsamością regionu, Zeszyty Naukowe Politechniki Poznańskiej, seria Organizacja i Zarządzanie, nr 70 (2016)
15. Siemieniak, M.: Analiza strat czasu pracy w zakładzie produkującym elementy maszyn (Analysis of work time losses in company producing machine parts), Zeszyty Naukowe Politechniki Poznańskiej, seria Organizacja i Zarządzanie, nr 35 (2002)
16. Skyttner, L.: General Systems Theory, Ideas & Applications, 460 p. World Scientific, Singapore (2001)

Psychosocial Toxicity in Colombian Service Companies

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Abstract. Work environments in Colombian companies have been affected by organizational practices that ignore the psychosocial factors, violating government initiatives in the workplace.

The objective of the study was to identify disruptors and establish predictors of working conditions that affect the health of employees. Study conducted in 7 Colombian companies with a population of 312 and sample of 190 workers. Signature of informed consent. Use of the Instruments Battery for the Evaluation of Psychosocial Risk Factors with levels of reliability in the questionnaires; intra - occupational 0,957; extra - occupational 0,944 and stress 0,83. The correlations verified toxic intra - occupational conditions that damage physical and mental health. It is determined as a disruptor, inadequate communication processes with noxious semantic force derived from the social and cultural context as a predictor of mobbing.

Keywords: Human factors · Disruptors · Work · Stress · Burnout · Mobbing

1 Introduction

Work environments in Colombian companies have been affected by organizational practices that insist on ignoring psychosocial risk factors. Some are unaware of legal labor initiatives, which leads workers to reduce their health by not knowing the levels of affectation. In addition, with the ignorance of values such as respect, good treatment and dignity for a healthy coexistence towards work scenarios free of arbitrariness and violence.

The World Health Organization makes a global review of persistent work stress considering it an epidemic, as it is the only occupational hazard that has the potential to alter or affect 100% of workers. Situation that causes disturbance in health, absences, decrease in individual development and productivity, as well as an increase in the appearance of occupational diseases, rotation and accidents [1].

McLean, states that the identification of the worker with the organization of work has received great attention from occupational medicine, clinical psychology, psychiatry and knowledge science. Focusing on psychosomatic reactions and the work accident of human etiology. Being the most recent, those that correspond to environmental emotional reactions such as the psychopathology of everyday life and its relation to the

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work process, the exercise of the different types of authority, the cohesive influence of the work group and productivity. Each specialty reflects on those responsible for the approach from a moral, ethical and social perspective of these precursors at any level of the organization [2].

The world of work in the last 10 years has been transformed in an important way in the sociocultural context. With the appearance of new work demands, new risks with psychosocial denomination have arisen, relating them to work stress and those that are a fundamental piece in studies or measurements of this order [3].

Ibarra, Cuban toxicologist, states that the current worker is subjected by his daily work to a variety of factors and processes potentially harmful to their health that differ in their nature and magnitude, classified these, in processes of a physical, chemical, biological nature, ergonomic and psychosocial which in their combination act on the organism of the worker for cause or on the occasion of the work environment and performance throughout their working life [4].

It must be specified that a worker has a contamination considered toxic when directly or indirectly in handling, closeness, use, transformation or storage of elements that release chemical substances that enter the body and that trigger, according to the dose, diseases or alterations in their health. This situation leads to the realization of studies that allow to determine the corresponding etiological agents, their properties, mechanisms of action in the organism, the essential control and prevention of their presence in the workplace [5].

In view of the foregoing and standardizing what derives from chemical industrial toxicology, we then make a parallel to alterations by work environments with toxic elements of the experience and personal relationship of the worker with conflicting personalities addressed from ergonomics and psychosociology as part of the factors and processes listed by the author in occupational toxicology [4]. Now, psychosocial alterations in workplaces arise from the appearance of a conceptual disruptor, understood as the effect on a rule or discourse established in such a way that it alters the semantic and pragmatic field of a communicative and relational process in a community with the capacity to alter one or several interlocutors [3].

The conceptual disruptor precarizes the semantic function without changing the meaning of the term. This, introduces confusion in the pragmatic function of the discourse, affects within the dynamics of dialogue and never alone [6].

Richar Dawkins in 1976 developed the concept of memetic socialization as the minimum unit of information in the cultural transmission that directly influences the communicative process [7].

For all the above, Colombia is currently carrying out important work from the legal recognition of psychosocial risks for the damage to the health of its workers.

For this reason, we see the need to develop a research process with a group of workers to verify precursors and possible disruptors from a psychosocial diagnosis intra - occupational.

2 Method

Applied, mixed and correlational research study. Identifies disruptors and establishes predictors of working conditions that affect the health of workers, verifies individual alterations and mobbing. Also, descriptive taking into account that the subject has not been very studied.

It is specified as correlational since it establishes causal relationships between the risk factors and the triggers of stress symptoms related to mobbing.

A population of 312 with a sample of 190 workers from service companies.

The inclusion criteria of the sample consisted in verifying in the occupational clinical history, the nonexistence of psychiatric illness, in addition to an incorporation in the company of more than 6 months.

Stages were defined for the development of the study, beginning with the sensitization stage that socialized the criteria and objective to be developed. In addition, signing voluntary informed consent by workers who participated in the activity, which allowed to define the sample as non-probabilistic.

The instruments used for this study were those of an individual nature that are part of the Instrument Battery for the Evaluation of Psychosocial Risk Factors [8].

These instruments based on models, Demand - Control - Social Support [9, 10] and the model, Imbalance - Effort - Reward [11], taking into account that the effort is evidence of work and the rewards are those that are received in the exercise of the same, establishing themselves as potential stressors because their combinations increase their harmful effect on health.

The stress measurement instrument is based on the JCQ model that differentiates situations for the identification of physiological symptomatology, social behaviour, intellectual, work and psychoemotional [12].

Conflict situations reported to the human resources department and the Labor Coexistence Committee were verified.

The instruments used have reliability levels, intra - occupational of 0,944; extra - occupational 0,88 and stress of 0,83. The results were related to the complaints presented to the Labor Coexistence Committee, with a correlation level of 62,5% and a reliability level of 0,85.

We collected information on sociodemographic characteristics that allowed us to determine an individual profile of the workers.

For mobbing, items that integrate each dimension of the psychosocial risk factor questionnaire intra - occupational in their forms A and B were verified and analysed, as possible triggering factors of mobbing. The domains analysed were leadership and social relations at work, control over work, work demands and rewards. Likert scales of 5 levels to mark a single answer, without risk or negligible risk, low risk, medium risk, high risk and very high risk.

2.1 Inventory of Used Instruments

Instruments. Informed consent, individual and occupational data sheet, questionnaire of psychosocial risk factors intra - occupational, form A, for chief workers or decision-makers; questionnaire of psychosocial risk factors intra - occupational, form B, for personnel who receive orders permanently; questionnaire for evaluation of stress and questionnaire extra - occupational, that has questions related to their family, housing and environment conditions.

The Mobbing, was identified with the report of situations contained in the instruments described above, according to the scores of medium risk levels, high and very high. Score in the domains of work demands, control and leadership and social relations.

We defined as application modalities, hetero - application and self – completion.

2.2 Phases of the Study

1st Phase. Application of instruments for the evaluation of psychosocial risk factors. The workers who agreed to participate filled out the instruments described in the previous item.

For the implementation of the proposed prevention measures, the prioritization was made for their attention under the following criteria of risk levels; Priority 1, very high and high; Priority 2, medium and Priority 3, low or no risk, which evidenced worker conditions.

Conditions intra - occupational, established as the characteristics of the work and its organization with the ability to influence health and well-being, with varied nature, quantitative, cognitive or mental, emotional, responsibility, the physical work environment and the working day. The following domains were defined:

Control over work, as the possibility of the individual to influence and make decisions about the various aspects involved in the realization of this. The initiative and autonomy, the use and development of skills and knowledge, the participation and management of the change, the clarity of the role and the training as aspects that give the individual the possibility of influencing their work, were determined.

Leadership and social relations at work, understands leadership as a type of social relationship between hierarchical superiors and collaborators.

Social relations at work, were determined as the interaction established with other people in workplaces.

The reward, like the retribution that the worker gets for his effort at work. This domain with two types of remuneration, the financial one that provides economic compensation and the one of esteem, as psychological compensation in the recognition of the worker within the social group.

Conditions extra - occupational, defined as the family, social and economic environment of the worker, which cover the conditions of the place of housing which may affect health and wellbeing.

Individual conditions, are considered as characteristics of the person; sex, age, marital status, educational level, occupation, city or place of residence, socioeconomic scale, the type of housing and the number of people who depend economically on the worker.

For the measurement of stress, a questionnaire was used with questions aimed at establishing symptomatology physiological, social behaviour, intellectual, work and psychoemotional.

2nd Phase. Determination of the presence of mobbing.

Situations of conflict reported to the human resources department and the Labor Coexistence Committee were verified.

The levels of risk obtained in the stress questionnaire were verified, which in turn allowed to identify the symptomatology in the workers.

The priority activities to be followed in the intervention plan were determined. For cases of individual attention of priority 1 and 2; and group attention with priority 3.

3rd Phase. Confirmation of the presence of mobbing.

Execution of semi - structured interview, for confirm, presence of mobbing, truth in the report or intimidation.

4th Phase. Identification of precursors and disruptors for psychosocial toxicology.

With the verification of the reasons for the complaint and the semi-structured interviews, it was possible to define and identify the precursors and disruptors with harmful potential in the health of the workers.

2.3 Population and Sample

A population of 312 and a sample of 190 workers with operational and chief positions.

3 Results

3.1 Individual Conditions

Population comprised by 36 women and 154 men. Ages 22 to 66 years old (Table 1).

Table 1. Marital Status of the Participants

Civil Status	n	%
Single	89	46,84%
Married	44	23,16%
Divorced	4	2,11%
Widower	1	0,53%
Separated	3	1,58%
Free union	49	25,79%
(in white)		0,00%
Grand Total	190	100,00%

A majority population with a family responsibility nexus (Table 2).

Table 2. Schooling of the Participants

Schooling (last level of studies)	n	%
Full graduate	5	2,63%
Incomplete postgraduate	4	2,11%
Full professional	57	30,00%
Incomplete professional	13	6,84%
Technical - Technological complete	58	30,53%
Technical - Incomplete Technology	24	12,63%
Full baccalaureate	19	10,00%
Incomplete baccalaureate	9	4,74%
Incomplete primary	1	0,53%
Grand Total	190	100,00%

35% of the population with studies over vocational training.

3.2 Intra - Occupational Conditions

It was found that the domain of leadership and social relations in the workplace, presents 66% of employees affected by communicative schemes in the relationship processes and conformation of work teams. The above coincided with 54% of workers affected by leadership characteristics and performance feedback.

60% of the population reported, in the demands of their activity and in the type of work, constant activities of permanent attention of people, business management focused on giving immediate response to activities without planning and just-in-time criteria that make the operation more stressful.

For control over work, 53% of the population reports verbal aggressions, variation of schedules and activities without planning, directly related to the stress symptomatology.

And regarding the domain of reward, 53% of the employees expressed that their remuneration is not adequate for the volume of work done, because the quality of life is depressed, and the income is not enough to cover their personal needs, without However, 47% affirm as positive, having stable paid work.

3.3 Extra - Occupational Conditions

80% expressed affectation in the times of rest and family relationship caused by interference of work situations in personal time.

The displacement, Housing - Work - Housing, evidence 59% of the workers affected by the difficulty of their trips to the workplace and extensive journeys that can be more than two hours due to the difficulty of taking transportation and vehicular congestion as a result of the mobility of the city.

3.4 Stress Conditions

The study revealed that 55% of workers expressed being affected by stress.

Below, the results are presented in Table 3 detailing the discomforts related to the symptoms of workers in the last 3 months:

Table 3. Disconforts that most affect the health of workers

Symptom	Disconforts	Affected Population
Physiological	Pains in the neck and back or muscle tension	16,31%
	Gastrointestinal problems, peptic ulcer, heartburn, digestive or colon problems	
	Headache	
	Sleep disorders such as drowsiness during the day or sleeplessness at night	
	Heart palpitations or heart problems	
Social behavior	Difficulty in relationships with other people	27,36%
	Sensation of isolation and disinterest	
Intellectuals and labor	Increase in the number of work accidents	3,68%
	Feeling of frustration, of not having done what was wanted in life	
	Tiredness, boredom or reluctance	
Psychoemotional	Consumption of alcoholic beverages or coffee or cigarette	7,89%

4 Discussion

4.1 Mobbing

After the application and verification of the results of the forms A and B, the correlations verified a 64% of high influence; 32% had medium - high, medium or medium - low influence with the total, and only 4% of the dimensions had a low, although significant influence.

The results of the correlations between the questionnaire of stress symptoms and the results of psychosocial risk factors intra - occupational form A and B, showed statistically significant results, establishing that the higher psychosocial risk caused by mobbing, the higher stress level.

When reviewing the scores of the risk levels and the complaints presented by the workers to the Labor Coexistence Committee, in addition to the incapacities that determined absences, evidence of acts tending to aggressions and verbal abuse was found, constituting proof of the existence of a direct relationship with the appearance of stress symptoms related to social alterations, difficulty in personal relationships in the workplace, feelings of isolation, loneliness and disinterest; psychological, such as frustration, injustice, sleep disorder, anguish, sadness; psychosomatic, causing occupational accidents with permanent and partial disabilities that have a negative effect on welfare and in some cases leads to the development of post-traumatic stress.

After having made the identification, we proceeded to the development of the intervention plan for individual attention cases of Priority 1 and 2 with immediate attention and referral to specialist, as well as Priority 3 group care, with gradual attention during the projected year in the intervention plan.

4.2 Psychosocial Toxicological Determinants

It was established that the precursors of mobbing in the organization are evidenced in the levels of risk of leadership and social relations at work, performance feedback, demands of work and control over work.

For conceptual disruptors, it was verified that the communicative processes developed among the workers, their socio-cultural origins, the exposure to situations of social violence, the untimely management of the organization with regard to an organizational culture, the little management in safety and health in work, the absence of priority in the promotion of respect and good working conditions, organizational management without planning and production only, preferences, little or no development towards empowering leadership, are our main findings that increase the level of toxicity for workers, making them a lethal dose if they do not intervene [13].

5 Conclusions

This study provides a baseline contribution to the public health of the knowledge of workers in the service sector to design promotion strategies, prevention and intervention of Psychosocial Risk Factors, in order to reduce the occurrence of disorders derived from work stress, caused by situations of high social and relational toxicity in work teams.

It is crucial to understand that the concept of psychosocial toxicology is incorporated into the technical concept of occupational toxicology, making a verification with the intoxication caused by the environment (precursors) and in which the life of the worker passes as an adrenergic reaction when subjected to a stressful situations (disruptors) that act on the chemical, metabolic and corporal action of the worker, leading to intoxication that when prolonged, has the capacity to alter his nervous system, tissues and organs (harmful potential) with physiological outcomes of incapacitating alterations that eventually trigger work-related illness and death (lethal dose).

This work opens the way for the development of research of the same or similar characteristics. It is suggested that they be developed by psychology and psychiatry personnel in the first place or those who are worried about going deeper into it.

Regarding the limitations of this investigation, it is determined that companies that do not have a work coexistence committee will not be able to easily verify possible mobbing situations, because said committee is in charge of receiving and mediating complaints in organizations.

It is important to emphasize that the Labor Risk Department of the Ministry of Labor of Colombia has directed resources and serious efforts for the structuring and national validation of labor psychometric instruments to evaluate psychosocial risk factors in companies. This is how these tools provide an opportunity for use in countries with similar conditions of work life styles and sociocultural conditions.

References

1. Valencia, C., Mora, O.: Acoso Psicológico en el Trabajo "Mobbing" en Empresas de Servicios Colombianas. Un Factor de Riesgo que se debe Controlar. Rev. Colomb. Salud Ocupacional. **6**, 20–25 (2017)
2. McLean, A.: Salud Mental en elTtrabajo: Revisión de un Arte Emergente. Am. J. Psychiatr. **122**, 961–976 (2006)
3. Piñeros, O., Marín, C.: Toxicología Psicosocial. Disruptores y Predictores. Una Mirada a Docentes Colombianos. In: ORP 2017. Psicosociología (2017)
4. Ibarra, F., Enrique, J.: Toxicología en Salud Ocupacional. Instituto Nacional de Salud de los Trabajadores, Cuba (2017)
5. Marín, C., Piñeros, O.: Nueva Estrategia en la Gestión Organizacional para la Prevención del Mobbing. Prev. Integral. (2018)
6. Garrido, F.: La Guerra Difusa, los Disruptores Conceptuales y el Humanismo Militar. Instituto de Filosofía, Barcelona (2005)
7. Dawkins, R.: El Gen Egoísta: las bases Biológicas de Nuestra Conducta. Oxford University Press (1976)
8. Ministerio de la Protección Social: Batería de Instrumentos para la Valoración de Factores de Riesgo Psicosocial (2010)
9. Johnson, J.V., Hall, H.E.: Job strain, workplace social support, and cardiovascular disease: a cross sectional study of a random sample of the Swedish working population. Am. J. Public Health, 1336–1342 (1998)
10. Karasek, R., Theorell, T.: El Modelo de Demanda - Control. Organ. Int. Trab. (1979)
11. Siegrist, J.: Adverse Health Effects of high-effort/low-reward Conditions. J. Occup. Health Psychol. (1996)
12. Vega, S.: NTP 604: Riesgo psicosocial: El Modelo Demanda - Control - Apoyo. INSHT, España (2001)
13. Piñeros, O., Marín, C.: Hombre, Trabajo y Salud. Condiciones para un mejor manejo del estrés? Mito o Realidad., Lima - Perú (2016)

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