Ergonomic Work Analysis of a Pathological Anatomy Service in a Portuguese Hospital

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Abstract Awkward and uncomfortable postures when maintained for long periods of time could stress and fatigue supporting muscles and tendons, leading to the development of musculoskeletal disorders (MSD). An Ergonomic Work Analysis was required to assess and evaluate the working conditions in a pathological anatomy laboratory. The objectives of this study were: assess the actual working conditions of the professionals in that service; establish relationships between them and the complaints presented; identify and select the most painful task/workstation, characterize this task/workstation in terms of the associated MSD development risk and, finally, identify and propose some preventive measures. The Rapid Upper Limb Assessment was used and the results revealed that the risk for the development of MSD is present in all tasks. The three most critical tasks were identified. Considering the self-reported physical symptoms, the results were similar with the other studies reported.

Keywords Musculoskeletal disorders (MSD) · Rapid upper limb assessment (RULA) · Binocular microscopes · Microtomes · Embedding centres

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1 Introduction

Awkward and uncomfortable postures are recognized as harmful in particular if they are maintained for long periods of time. These postures are usual among pathologists and other technicians due to some particularities of the tasks they are required to complete, namely while using binocular microscopes, microtomes and embedding centres. The association of prolonged microscope use with the development of chronic pain syndromes has been recognized for nearly 3 decades [1]. This situation is common in these professionals due to the number of risk factors associated with the tasks performed by them every day such as: the force, the posture, the repetition required by the task and the level of precision and attention required. In other words, all these situations may stress and fatigue supporting muscles and tendons, leading to the development of musculoskeletal disorders (MSD) [2].

Therefore, an Ergonomic Work Analysis was required to assess and evaluate the working conditions in a pathological anatomy laboratory.

This study integrates five main objectives:

- Assess the actual working conditions of the professionals in that service;
- Establish relationships between them and the complaints presented;
- Identify and select the most painful task/workstation;
- Characterize this task/workstation in terms of the associated MSD development risk and, finally;
- Identify and propose some preventive measures.

2 Materials and Methods

2.1 Stages of the Study

This study comprised 3 fundamental stages which integrate different kinds of objectives. The first stage named—Characterization of the Work Situations—integrated the three first objectives, the second stage named—MSD risk characterization—integrated the fourth objective and, the last stage named—Preventive measures—integrated the fifth and last objective.

- 1st stage—Characterization of Work Situation—included characterization of both the operators and the service and a task analysis, e.g., task identification and characterization, in terms of prescribed objectives as well as in terms of general executing conditions (this step without much rigor).
- 2st stage—MSD risk characterization—included the application of Rapid Upper Limb Assessment (RULA) find if the risk for the development of MSD was

presented in the selected tasks. Other analyses were included to better characterize the workstation associated with the tasks selected.
- 3rd stage—Preventive measures—Included some of different kinds of preventive measures such as technical and organizational measures.

2.2 Data Collection and Procedures

For data collection, we used different methods, tools and equipment, in accordance with the specificity of stage of the study.

1st Stage The study began with the characterization of the work situation and workers relying on different methods: Conversation or dialogues with workers which were crucial for the identification of relevant information which was included in a questionnaire specifically developed to further characterize the work situation; Documental Analysis (e.g.: task procedures, service organization chart, material safety sheet, tools instructions,…); Free and systematized observations; As we said before for a better characterization of the situation, a questionnaire was specifically developed. The questionnaire was applied during the 1st stage of the study and it intended to identify key parameters for the workers' characterization, evaluate their perception of the real working conditions, as well as to identify self-reported symptoms of annoyance, discomfort and physical pain, eyestrain and mental fatigue. The questionnaire results and the sensibility of the workers were important to select the tasks to integrate in the 2nd stage of the study. The questionnaire developed results from an adaptation of the questionnaire proposed by Carvalho [3] and the questionnaire used by Serranheira et al. [4].

To participate in this study a previous verbal consent of the operators involved was obtained. The workers responded to the questionnaire independently and anonymously. All workers (N = 40) involved in that service were invited to participate in this stage of the study. Therefore, different types of workers' activities and their workstations were observed, resulting in 32 workstations analyzed.

2nd Stage To provide a better characterization of the workplace associated to the tasks selected, the noise, the lighting and the thermal environment variables were measured. Therefore, the environmental variables only were assessed after the tasks had been selected and during this particular stage of the study.

Noise was measured with a Bruel & Kjaer Sound meter, 2260 model, which was carefully placed near the operator's ear. The device was subjected to verification in the workplace before each series of measurements. Both Continuous A-Weighted Sound Pressure Level (dB(A)) and Maximum Peak Level (dB(C)) were measured. The noise was assessed in a total of 8 workstations. Among these workstations we have: 3 that implicate the use of microtomes; 3 that implicate the use of microscope, and 2 embedding centres.

Fig. 1 Flowchart illustrating the RULA methodology applied

The illuminance (lux) level was assessed with a digital Krochmann lux meter, 106E model, which was strategically put on the surface of the workstations. In particular near the place where the subtasks or technical actions that involve high levels of precision and attention were accomplished, in each task. The illuminance was assessed in a total of 13 workstations. Among these workstations we have: 3 that implicate the use of microtomes; 8 that implicate the use of microscope, and 2 embedding centres.

Finally, the thermal variables (dry (Ta) and wet air temperatures) were assessed with a THIES sling psychrometer—450 model. Air humidity (Hr) was computed from these two variables; for each workspace, three measurements were made with the equipment on the center of the workspace (medical office or laboratory) and the average value was used as reference. The thermal evaluations were made in 3 medical offices, the cytology laboratory and the histology laboratory.

For dimensional characterization of the workstations, associated with the tasks selected, several dimensions of the work surface and of the equipment used were collected resorting to a measuring tape.

Image and video recording were included to collect images related to work activity. For this purpose a digital camera with 13 megapixel and 1920 × 1080 (16:9) resolution was used.

To characterize the associated risk of MSD development, by each task selected, the Rapid Upper Limb Assessment (RULA) was used. A complete description of the RULA method can be found in the works written by McAtamney and Corlett [5, 6].

In terms of methodology RULA was applied considering the flowchart illustrated in Fig. 1.

At the end we used the average scores obtained for each task/subtask considered. This method was applied 167 times and 13 workstations were analyzed in terms of the biomechanical load. Among these workstations we had: 2 that use embedding centres, 5 that implicate the use of microtomes; 6 that implicate the use of microscope.

2.3 Data Processing

For data processing, we resorted to the Statistical Package for the Social Sciences (SPSS©). Descriptive analyzes were performed using location (Mean, Mode, Percentiles) and dispersion (ranges, standard deviation) parameters.

Table 1 Illuminance level (lux) recommended considering the different kind of exigence in workstation

Task	Illuminance level (lux) EN 12464-1 de 2002	Illuminance level (lux) NF_X35-103
Laboratory (general illuminance)	500	750
Task with high visual and attentional demand	1000	1500

The Action Level 2 of RULA method, which represents the final Grand Score Rula (GSR) equal to Score 3 or 4, was considered the level from which a high level of MSD development is present.

For each task assessed the load ranking was based on biomechanical criteria. With this purpose, The Score A and Score B, available with RULA application, were highlighted. The Score A gives us the biomechanical load considering how much the upper limbs (the upper arm, lower arm, wrist and wrist twist) are involved in doing the task and Score B gives us the biomechanical load considering the use of neck, trunk and legs.

To evaluate the noise level, the values recommended by NBR 10152:1987 [7]—a Brazilian standard—were used. For this standard, 50 dB(A) is considered the value from which the workers exposed will be experiencing acoustic discomfort.

To interpret the illuminance (lux) level, the values recommended by BS EN 12464-1:2002 [8]—a British standard—was used and after all, the values were corrected by the level proposed by NF_X35-103—a French standard [9]. These corrections considered variables such as: age (>45), reflection and contrast factors, error relevance, task frequency, lack of natural lighting. Table 1 shows the recommended values by each standard used.

To interpret the thermal variables we used the values proposed by Portuguese legislation: Dec-Lei no. 243/86 de 20 Agosto [10], which recommends:

- 18 °C ≤ Ta ≤ 22 °C;
- 50 % ≤ Hr ≤ 70 %.

3 Results and Discussion

3.1 Workers' Characterization

75 % of the professionals working in that service agreed to participate in the study, which represented 30 out of the 40 workers. Out of these workers (N = 30), 28 were female and 2 were male. Considering the age, these workers had an average of 44 years old (28–65 years). More than 50 % of the workers had more than 45 years old (Fig. 2); in terms of Seniority, this service has a high level of seniority (60 % of the workers had more than 10 years—Fig. 3).

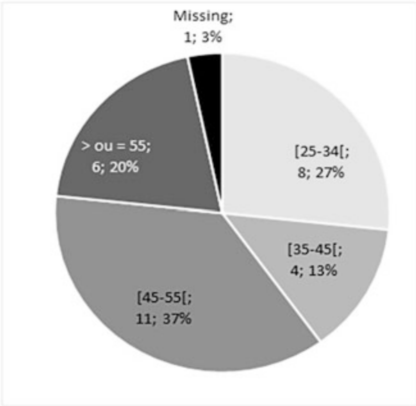

Fig. 2 Workers' distribution by age groups

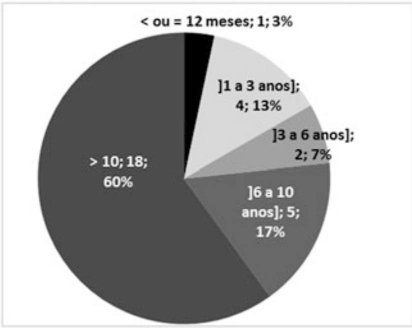

Fig. 3 Workers' distribution by Seniority groups

3.2 Work Organization

In terms of work organization this service has no rigid schedule, working between 8:30 and 17:30; All workers did work breaks, where they had the freedom to choose the duration and frequency and 60 % of the workers did overtime, at least, one time per week.

3.3 Workers' Job—Task Associated

In terms of Workers' Job and Task associated 23 % of the workers that participated in the study were pathologists, which are the workers responsible for Observation and Diagnosis under the microscope; 43 % were Diagnostic and therapeutic technicians, which were responsible for preparing all the procedures to make possible the Observation and diagnosis of histological and cytological analysis and may also assist in performing autopsies; 27 % were Technical assistants, which were responsible for all Lab secretarial work and, finally, 7 % were Operational technicians, which were responsible for Cleaning of work equipment and lab benches.

3.4 Self-reported Symptoms Results

Considering the self-reported symptoms (annoyance, discomfort and pain) it was possible to identify the main corporal regions affected with a high level of prevalence of symptoms for the total jobs integrated in that service: cervical (66.7 %) dorsal (43.3 %) and lumbar (53.3 %) spine, right shoulder (43.3 %), right wrist (46.7 %) and right hand (53.3 %). These results are similar to the results reported by other studies [1, 11]. Figure 4 shows the main regions where complaints prevail by each workers' jobs. Considering that for the Operational technicians, only one answer was obtained for this part of questionnaire, we decided not to include them in this analysis to assure the confidentiality of data.

Considering visual and mental fatigue, 87 and 73 %, respectively, were reported by workers. 54 % of the workers that reported visual fatigue considered that this symptoms had some impact in perception of information. In terms of Visual Fatigue, the main symptoms appointed were: Blurred vision; Itchy eyes and, Red eye. In terms of Mental Fatigue, the main symptoms referred were: Decreased concentration and attention; Mood swings/ irritability and, Extended outage in time.

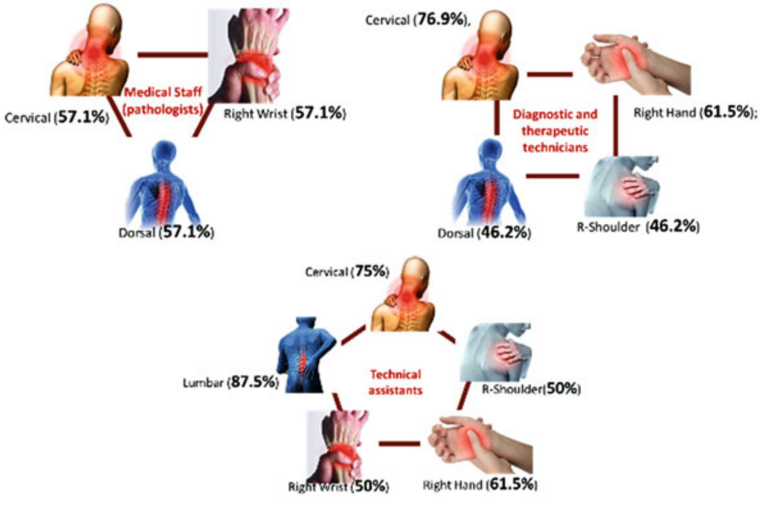

Fig. 4 Main corporal regions with prevalence of complains

3.5 Association Between Age/Seniority/Job and Annoyance/Discomfort/Pain, Visual Fatigue and Mental Fatigue

In all categories of Age groups, Seniority groups or Job, the workers experience some kinds of Annoyance/discomfort or/pain, Visual fatigue and Mental Fatigue (Figs. 5, 6 and 7). Considering these results we can assume that Age, Seniority and Job seem to have no specific association with the presence of symptoms of Annoyance/discomfort/pain, Visual and Mental fatigue but suggest that the work conditions is an important variable that could be responsible for that.

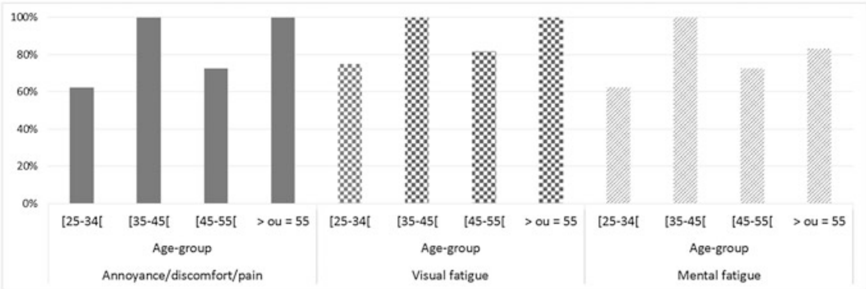

Fig. 5 Physical complaints (annoyance/discomfort/pain)/Visual Fatigue and Mental Fatigue by Group age

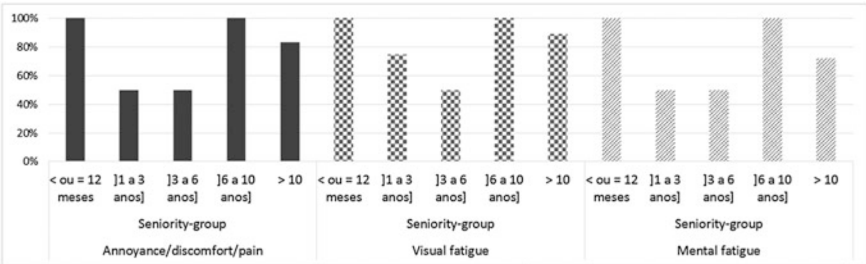

Fig. 6 Physical complaints (annoyance/discomfort/pain)/Visual Fatigue and Mental Fatigue by Group seniority

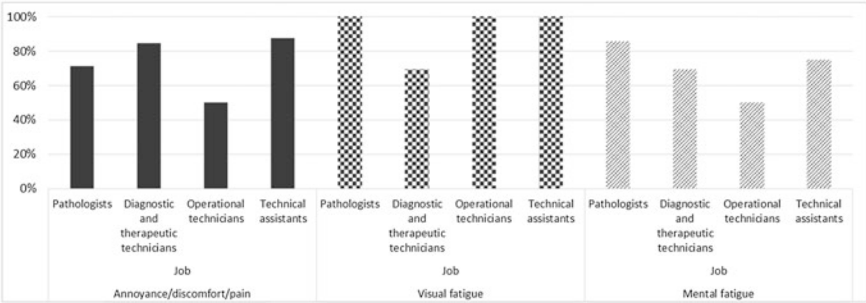

Fig. 7 Physical complaints (annoyance/discomfort/pain)/Visual Fatigue and Mental Fatigue by Job

3.6 Critical Tasks Selected and Tasks' Characterization

Three most critical tasks were identified: Microscope Observation and Diagnosis; inclusion of fragments in paraplast blocks and Cutting paraplast blocks in microtomes (2nd Cut). The main reasons pointed were: static position maintained throughout the working day; high liability associated with the diagnosis; high manual accuracy and visual attentional demand; inadequate chairs and microscopes and, lighting problems. Table 2 synthesize the main characteristics of the tasks selected regarding some of the parameters considered and main critical movements/postures or constraints observed.

3.7 Environmental Results

Considering the noise assessment, even though the results obtained do not represent risk for workers' health, they can experience acoustic discomfort (L_{Aeq} > 50 dB(A)).

Considering the task accomplished in that service, the results of dry temperature were higher than the recommended values.

In terms of illumination, 17 % of the measures made revealed that the Illuminance level (lux) obtained were higher than recommended. The main reason appointed was lack of protection on the windows. In the other all cases the Illuminance level (lux) obtained was not sufficient for the tasks developed.

These results may justify complaints presented by workers, which consider that:

- 43 % considered noise was very uncomfortable or uncomfortable;
- 43 % considered lighting was nothing suitable or unsuitable;
- 36.6 % considered thermal environmental was very uncomfortable or uncomfortable.

Table 2 Synthesis of main characteristics of the tasks selected regarding some of the parameters considered and mains critical movements/postures or constraints observed

	Task assessed		
	Microscope observation and diagnosis	Inclusion of fragments in paraplast blocks	Cutting paraplast blocks in microtomes (2nd cut)
Number of workstations assessed	6	2	5
Work cycle time (average)	Variable	50 s	60 s
Task duration	≥8 h/day	1.5–3 h/day	1.5–4 h/day
N of Technical actions (TA)	7	11	13
Workstation height	Very variable	97.6–101.5 cm	≈89.3 cm
Equipment used	Chair and desk; microscope Computer; keyboard, mouse	Chairs and embedding centres	Chairs, benches and microtomes (with several different characteristics)
Main constraints observed	– Some microscopes don't permit any regulation – High flexion of the neck – Compression of soft tissues (wrist and forearm) – Suspended arm – Some operators need footrest – Inadequate regulation of the equipment to the workers	– Shoulder abduction for almost the entire work cycle time – High amplitude of flexion in reach sub-tasks – Pronation during the whole working cycle (left hand) with high level in some TA – Pincer grip of both hands – Compression of soft tissues (wrist and forearm) – Suspended arm during all the task time	– High level of reach in some TA – Different kind of regulations and cut mechanisms; – Medium-high flexion of the neck to see the cuts – Simultaneous trunk rotation and side flection (left side) to do some TA – Suspended arm – Lack of rested back posture, workers didn't lean against the chair

3.8 RULA Results

Considering the RULA results, the risk for the development of MSD is present in all tasks (GSR > 3). The inclusion of fragments in paraplast blocks was the task with the lowest Grand Score Rula (GSR = 3.385). However it was the task that presented a higher value for Score A (Score A = 3.9), which means more stress on the upper limbs. Cutting paraplast blocks in microtomes (2nd Cut) was the task with

Table 3 Synthesis of scores and average score obtained with RULA by Task

Task	ID	Score A (upper arm)		Score B (neck, trunk, legs)		Grand score RULA	
		χ score	$\bar{\chi}$	χ score	$\bar{\chi}$	χ score	$\bar{\chi}$
Inclusion of fragments in paraplast blocks	1	3.92	3.90	2.83	3.03	3.33	3.39
	2	3.89		3.22		3.44	
Cutting paraplast blocks in microtomes (2nd cut)	1	3.47	3.85	3.29	3.29	3.59	3.76
	2	3.95		2.84		3.42	
	3	4.05		3.05		3.82	
	4	3.9		4.1		4.3	
	5	3.88		3.18		3.69	
Microscope observation and diagnosis	1	3.5	3.73	2.38	3.25	3.13	3.70
	2	3.81		3.81		4	
	3	3.4		3.3		3.4	
	4	3.56		2.56		3.22	
	5	4.67		4.67		5	
	6	3.46		2.8		3.46	

higher Grand Score Rula (GRS = 3.764), the most prejudicial for neck, trunk and legs (Score B = 3.292) and the 2nd worst for upper limbs (Score A = 3.85). Microscope Observation and Diagnosis was the task that obtained lower Score A (Score A = 3.73) and the 2nd task that obtained higher value in Score B (3.253) and in Grand Score Rula (GSR = 3.702). Table 3 synthetizes the scores obtained with RULA by task.

4 Solutions Proposed

Some organizational and technical solutions were proposed to reduce the results obtained and complaints presented by workers.

4.1 Organizational Solutions

Workers Training Employers should train workers to be aware of their posture and better understand the MSD problematics. For this reason, workers should be encouraged to:

- Adopt neutral postures;
- Keep frequently used instruments and work materials within close reach;

- Diversify activities, change position, and take short breaks, at least, every 60 min to rest muscles and increase blood circulation;
- Adjust, when possible, the position of work, the work surface, or the chair so that you can sit in an upright, supported position;
- Sit close to the work area, keep objects close and adjust the chair to match the height of the bench.

When worker needs to work with both, Computers and Microscops, more attention should be given, to

- Sitting close to the work surface;
- Adjusting chair, workbench, or microscope as needed to maintain an upright head position;
- Elevatting, tilting or moving the microscope close to the edge of the counter to avoid bending their neck;
- Taking short breaks. Every 15 min, close the eyes or focus on something in the distance;
- Avoid leaning on hard edges;
- Using Pad forearms and edges;
- Keeping elbows close to their sides;
- Keeping scopes repaired and clean;
- Placing monitor so the top of the screen is approximately at eye level;
- Using footrests, where possible, in order to allow changing leg positions throughout the day.

Note: Where there are multi-users in the same workstation, more attention should be given to its adjustment.

4.2 Technical Solutions

Changes in Layout

- Where possible, position computer workstations in corners or other areas away from doors, entrances and passageways;
- Monitor and keyboards should be positioned perpendicular to the windows;
- Increase the luminous flux of localized illumination in embedding centres so that the level, in work surface, be around 1500 lux;
- Replace yellow bulbs, in embedding centres, with white bulbs, which have better color rendering index;
- Decrease the luminance of the work surface used in microtomes, with a dark-colored film;
- Control the illuminance level (lux) using blinds or curtains;
- Redesign the workplaces considering, when possible, that, workers should sit parallel to windows rather than facing them or sitting with their backs to them;

- Remove the drawers blocks under desks ensuring that the undersurface of the desk, both front to back and side to side, allows users to move their legs freely and change position without hindrance;
- Incorporate handle in order to maintain a neutral wrist position, on manual microtome used in one of tasks.

Choosing New Equipment Always when needing new equipment some attention should be payed to these tips:

- Choose adjustable microscopes (with tilting and telescoping eyepieces) or adapt existing microscopes with longer ocular tubes, platform adapters, etc.;
- Choose chairs/desks and adjustable equipment;
- Provide a foot rest to help workers adjust their body position.

5 Conclusions

This study has revealed that the work done in this pathological anatomy service entails risks for its employees who may be responsible for the development of musculoskeletal disorders. These results are similar with the results reported by other studies [1, 11].

Workers should be trained regarding MSD risk factors, as well as on how to fit the workstation to their needs. Some guidelines to regulate the equipment used or to buy the new one are among the advice given.

References

1. George, E.: Occupational hazard for pathologists: microscope use and musculoskeletal disorders. Am. J. Clin. Pathol. **133**, 543–548 (2010)
2. Navsafecen: Ergonomic microscopes reduce the risk of musculoskeletal disorders at naval health research center's respiratory disease laboratory, http://www.public.navy.mil/navsafecen/Documents/SuccessStories/082_Ergo_Scopes.pdf
3. Carvalho, F.: Estudo comparativo entre diferentes métodos de avaliação de risco, em situação real de trabalho (2007)
4. Serranheira, F., Pereira, M., Santos, C.S., Cabrita, M.: Auto-referência de sintomas de lesões músculo-esqueléticas ligadas ao trabalho (LMELT) numa grande empresa em Portugal. Saúde Ocup. Rev. Port. Saúde Pública. **21**, 37–47 (2003)
5. Mcatamney, L., Corlett, E.N.: RULA: a survey method for the investigation of world-related upper limb disorders. **24**, 91–99 (1993)
6. McAtamney, L., Corlett, N.: Rapid upper limb assessment (RULA). In: Stanton, N., Hedge, A., Brookhuis, K., Salas, E., Hendrick, H. (eds.) Handbook of Human Factors and Ergonomics Methods. pp. 7–1–7–11. CRC PRESS, Florida, USA (2005)
7. ABNT: NBR 10152:1987—Níveis de ruído para conforto acústico. ABNT—Associação Brasileira de Normas Técnicas, Rio de Janeiro (1987)

8. BS EN 12464-1:2002—Light and lighting. Lighting of work places. Indoor work places. Br. Stand. Inst. (2002)
9. NF X35-103 Juin 2013—Ergonomie—Principes d'ergonomie applicables à l'éclairage des lieux de travail. AFNOR (2013)
10. Decreto-Lei n.o 243/86 de 20 de Agosto—Regulamento Geral de Higiene e Segurança do Trabalho nos estabelecimentos Comerciais, de Escritórios e Serviços. Diário da República—I —n.o 190. 1a Serie, 2099–20105 (1986)
11. Sillanpää, J., Nyberg, M., Laippala, P.: A new table for work with a microscope, a solution to ergonomic problems. Appl. Ergon. **34**, 621–628 (2003)