Risk Assessment of Musculoskeletal Disorders in an Electronic Components Company

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***Abstract*—**The work presented in this paper was performed for a workstation of an assembly section in a company that manufactures radio modules and air conditioning for cars. After performing a workstation analysis and a questionnaire to the operators it was possible to understand the need to investigate the risk of musculoskeletal disorders originated from both the handling of loads as the incorrect dimensioning of the workstation. Regarding the handling of loads the NIOSH Equation was used and it was verified that there was no risk of musculoskeletal disorders. As the operators expressed their lack of satisfaction regarding back pains due to posture adopted they were established the appropriate dimensions (to satisfy 97.5% of the population and using the table of anthropometric data of the Portuguese population) for the workstation and it was proposed the availability of a chair for the workers.

***Keywords*—**Anthropometry, Musculoskeletal disorders, NIOSH Equation.

I. Introduction

ERGONOMICS is defined numerous times as the science that studies human-machine interaction, being its main objective the adaptation of work to man [1]. For this purpose, the knowledge of the measurements of the human body, i.e., anthropometric characteristics, is fundamental in the design of workplaces [2]. The great human variability is a barrier to the design of workstations, so it is important to develop anthropometric data bases relating to various types of population [3], [4]. In industry, the design of workstations is often arbitrarily, giving little attention to anthropometric measurements. However, these dimensions are of great importance from the viewpoint of production efficiency and the physical and mental well-being of operators [5]. The main result of the inadequacy of workstations and the adoption of bad postures is the emergence of work-related musculoskeletal disorders (WRMSD) and fatigue [6].

The manual handling of loads (MHL) is one of the most common causes of injuries arising from work [7]. All tasks associated with MHL, i.e., pulling, pushing, carrying and handling, can be critical situations from the point of view of the risk of WRMSD [8], [9]. To assess the risk of WRMSD associated with handling of loads there are several methods that have different approaches, considering different types of risk factors. In this sense, the choice of an appropriate method is critical to the success of the evaluation [10]. The NIOSH Equation proposed by the American Institute of Occupational Safety and Health (NIOSH) [11], is one of the methods used to assess the risk of WRMSD and most often cited in the bibliography. However, its implementation requires a detailed knowledge of the workstations to analyze (e.g. frequency, duration of tasks and distance traveled with the load).

In this paper it is presented the assessment of the risk of WRMSD in a specific workstation of a company. The workstation analyzed in this project belongs to the Portuguese subsidiary of a multinational company, located in Trofa, which manufactures automobile components. In this company, it was only analyzed one of the most representative sections where radio and air-conditioning modules for cars are produced, since it is the only one where there is significant handling of loads. In this workstation, the work is very thorough and carried out during the entire work period in the standing position. Thus, given the physical burden, it becomes evident the need for an anthropometric study of the workplace in order to understand the risk of WRMSD associated with the workspace design. Thus, the aim of this study was to perform a risk assessment of musculoskeletal injuries related to work which may result from handling loads and from the existence of workstation incorrectly sized.

Fig. 1 Workstation under study

II. Methodology

In the workstation studied (Fig. 1) it is assembled the screen of the car radio. To perform this operation, first, the operator places the items that arrive from the upstream workstation on the machine that is located in front of her. After that, with those items she performs the assembly operations. Finally, the operator places the finished product in a box that, when full, is elevated to a considerable height, to be used in the downstream workplace.

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To achieve the proposed objective, measurements were made in the workplace through direct observation and by interviewing the operators. This was very helpful to understand the opinions of the various operators regarding the conditions of the workstation.

Since the existence of manual handling of loads is not the ideal situation for operators' comfort, it was necessary to understand whether there was any risk of developing musculoskeletal disorders related to lifting the box. In this context, and using (1), it was determined the Recommended Weight Limit (RWL), of the load in order not to cause any WRMSD.

$$\mathrm{RWL} = LC \times HM \times VM \times DM \times AM \times FM \times CM \qquad (1)$$

where, LC (Load Constant), HM (Horizontal Multiplier), VM (Vertical Multiplier), DM (Distance Multiplier), AM (Asymmetric Multiplier), FM (Frequency Multiplier) and CM (Coupling Multiplier) represent the various multipliers.

After that, it was also important to assess the risk of WRMSD that the currently used box has, by determining the lifting index (LI), applying the formula given in (2):

$$Lifting \cdot Index = \frac{Actual \cdot Weight}{RWL} \qquad (2)$$

Through the questions posed to the operators it was possible to understand that one of the most reported problems is associated with the working posture they have to adopt during all the working hours - standing posture - which causes excessive tiredness, as they stated. Another of the most critical aspects was related to the constraints of space, since there are many workstations with an extremely small working area. Additionally, operators also reported having severe back pain, possibly due to improper sizing of the workstation.

The first problem (standing posture) could be solved by using some ergonomic interventions, such as placing chairs or sit-stand chairs, footrests or anti-stress mats. Once in the workstation under analysis there are just standing postures, the solution that would have more benefits for operators as regarding the prevention of WRMSD would be the provision of a chair or a footrest for temporary use, whenever necessary. The sit-stand chairs is very suitable for works performed in the standing position, however, despite bringing many benefits, using these chairs can also bring problems in blood circulation in the lower limbs, resulting in leg swelling [12]. On the other hand, when using a regular chair this circulation problem has no longer this much impact. In this sense, it was decided to select chairs with adjustable height and footrest, also adjustable. Thus, it became necessary to make some calculations (using (3)) to determine the dimensions of the chair to meet 97.5% (so that the number of people who cannot adapt to the workstation is minimal) of the population of both sexes, using the anthropometric data of the Portuguese population (defined from a study conducted at the University of Minho) [13].

$$\mathrm{P}(p) = m + s \times z(p) \qquad (3)$$

where, P(p) represents the percentile, m the mean, s the standard deviation and z(p) the value of the Normal distribution.

Since the operators expressed dissatisfaction with the sizing of workstations it was necessary to determine the various dimensions that a workstation should have. To make the correct sizing of a workstation it is necessary to take into consideration several factors. According to Chengalur et al. [14], it is necessary to determine seven measures, represented in Fig. 2 by A, B, C, D, E, F and G.

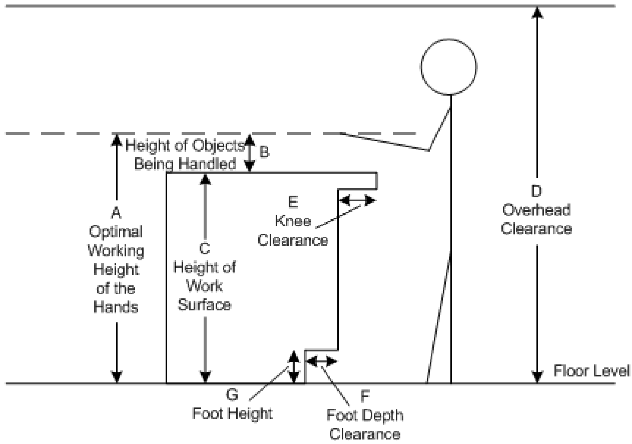

Fig. 2 Measures to consider in the sizing of a workstation (adapted from Chengular et al. [14])

Also in this case it was necessary to perform calculations to determine these dimensions to meet 97.5% of the population of both sexes, using the anthropometric data of the Portuguese population.

III. Analysis and Discussion of the Results

As regards the risk of WRMSD due to the manipulation of loads, the values of the several variables and of the multipliers that have been calculated with the NIOSH Equation are shown in Table I.

TABLE I
VALUES OF THE MEASURES AND MULTIPLIERS USED IN THE DETERMINATION OF RWL

Measure	Multiplier
L = 40cm	LC = 23
H = 40cm	HM = 0.625
V = 80cm	VM = 0.985
D = 60cm	DM = 0.895
A = 135º	AM = 0.568
F = 0.2elevations/min	FM = 0.850
C = good	CM = 1

By applying the NIOSH Equation it was obtained a value for the recommended weight limit of 6.12kg. As the RWL (6.12kg) is greater than the actual weight (2.80kg) it is obtained a lifting index lower than 1, i.e. 0.46. This value of

LI shows that under these conditions, and using the NIOSH Equation, to meet 99% of men and 75% of women, there is no inherent risk to this task of load lifting.

However, this information can be misleading, since this method is very general and has some limitations. In the NIOSH Equation not all the factors determining the risk of WRMSD are considered in the manipulation of loads and as such, when using a more detailed method the result could be different. According to Colim [10], for the cases of load lifting with both hands performed by an operator in a period not exceeding 8 hours, the most appropriate methods for risk assessment are the Mital's Guide to Manual Materials Handling, the NIOSH Equation, Liberty Mutual Manual Materials Handling Tables, the WAL&I calculator, the KIM method, the MAC method and the Hidalgo model. Another option would be to use the RULA method (Rapid Upper Limb Assessment) as it only studies the movements of the upper limbs. However, despite the assessment obtained using the NIOSH Equation has demonstrated no risk of WRMSD, changes to the workstation could be made so that it was not necessary to perform the elevation of the box. This improvement could be achieved by placing a mechanism (e.g. conveyor) along the workstation that would make the box reach the downstream workstation.

For sizing the workstation, according to Pheasant [15], there are some dimensions that are predetermined and are not required to ascertain the calculations. These dimensions are the leg space and the foot space. The leg space (E) should be 450mm at the knees' level and 650mm at feet' level. However, in this case it was decided to determine this dimension to meet 97.5% of the Portuguese population, yielding a value of 686.24mm. The foot space, both in height (G) and in depth (F) should be at least 150mm. The remaining dimensions were calculated through Equation 3 presented in the previous section. The height of the workstation (C) should be 1124.96mm; however, as this dimension was determined to meet the needs of the tallest operators it is required to make available a platform with a height of 275.12mm, for shorter operators. The values of all the given dimensions are summarized in Table II.

TABLE II
DIMENSIONS OF THE WORKSTATION TO SATISFY 97.5% OF THE POPULATION

Measure	Multiplier
A	1324.96
B	200.00
C	1124.96
D	2239.24
E	686.24
F	150.00
G	150.00

By correctly sizing a workstation, the probability of occurrence of WRMSD is reduced significantly. When the dimensions are determined to satisfy 97.5% of the user population, there is less tendency to adopt incorrect postures and performing irregular and unnecessary movements. The current height of the workstation is 800mm, i.e., about 300mm below the proper height. Even if the calculation of the height of the workstation had been done considering the reach of the shorter operators, the actual height would be 50mm below the level required. It is therefore possible to verify that the complaints from operators regarding back pain can easily be solved by raising the workstation.

Finally, the introduction of the chair at the workstation, to be used whenever necessary, shall have a minimum height of 836.16mm and a maximum height of 970.56mm. As for the width it must be at least 468.60mm and the depth should be 436.20mm. Once the table has been designed to work on a standing posture; the height of the chair will be very high, which will cause the operators to not reach the ground with their feet. In this sense, it was necessary to choose a chair with feet support. Thus, the maximum height of the support would be 625.64mm and the minimum height of 348.44mm.

Due to economic constraints inherent to the present conjuncture, the implementation of this proposal can be difficult, since it has a cost of 200€/unit. However, it is clear that the possible advantages, in the long term, of implementing this type of seats would be a profitable investment. By making the workspace more enjoyable and comfortable for operators it is possible to increase their motivation and commitment, increasing productivity and decreasing absenteeism.

IV. CONCLUSION

This study was conducted in a company that produces automotive components, specifically in a workstation of one of the sections that produces radio and air-conditioning modules. When analyzing the workstation it was found that there was manual handling of loads which could cause WRMSD. Additionally, by questioning the operators it could be understood that they feel dissatisfied with the working posture adopted during the entire shift and with the sizing of their workstations. In this sense, it was performed a risk of WRMSD assessment analysis caused by handling loads, using the NIOSH Equation. The result obtained, despite being positive (there was no risk in handling the load) cannot be completely accurate, since this method has some limitations.

Regarding the dissatisfaction with the posture adopted in the workstation, the necessary dimensions to properly size the workspace were determined, to meet 97.5% of the user population. Additionally, it was proposed to introduce an adjustable seat for operators to use if they had the need, with dimensions suitable for the existence of comfort during labor. Despite the advantages, these proposals may not have a high degree of acceptance with company management, to the extent that they represent a relatively high investment. However, it is clear that, with the proposed changes the work environment would become more harmonious and comfortable for operators.

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