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Ergonomic Assessment of Warehouse Activities in an Electric Utilities Company

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ABSTRACT

Work-related musculoskeletal disorders (WRMSD) constitute a significant problem in modern societies since they are responsible for occupational injury and disability. As a result, financial losses affect people, organizations, and society. Manual materials handling (MMH) activities are performed in many workplaces in several sectors of economic activity. They are one of the leading causes of WRMD in the lumbar region. One concern of Ergonomics is to reduce the risk of MMH activities and preserve the safety and health of workers. Several assessment methods have been developed to guide MMH risk assessment. The present study aims to analyze the risk of three MMH activities daily performed by warehouse workers. It was developed at a Portuguese electric utilities company. Six assessment methodologies - Revised NIOSH'91 Equation, Hidalgo Model, Shoaf Model, Mital Guide, KIM, and RAMP I – were applied to quantify the risk. A comparative analysis was carried out based on the results obtained by each methodology, and a ergonomic intervention measures were suggested to eliminate, or at least reduce, the risk.

Keywords: WRMSD, MMH activities, Risk analysis, Ergonomic intervention

INTRODUCTION

The lack of match between workers' abilities, limitations, and needs regarding their occupational activities is a cause of concern to our society since, in a long-term, it can lead to work-related musculoskeletal disorders (WRMSD) (Nunes, 2007).

WRMSD are one of the leading causes of work absence. They affect both the worker, by compromising his health, and the company, which is responsible for medical expenses and compensation for its employee (Grooten & Johansson, 2018; Keyserling & Chaffin, 1986).

Ergonomics assumes high importance in this context since it can help to minimize the prevalence of WRMSD, improving the worker's well-being and contributing to productivity (Pimparel, 2022). Specific methodologies have been developed to analyze ergonomic risk factors, namely manual materials handling (MMH) activities (Berlin & Adams, 2017).

MMH is any operation of moving or handling a load by lifting, lowering, pushing, pulling, carrying, restraining or holding. It is commonly related to occupational fatigue, low back pain, and a high risk of developing WRMSD, especially in the lumbar region (HSE, 2012; De Magistris, 2013).

Nowadays, MMH is still one of the most frequent tasks performed in the occupational context, particularly in the industrial sector. Ergonomic studies are essential to assess the risk of disorders in real contexts and plan the recommended interventions (Grooten & Johansson, 2018).

The present study was developed in a Portuguese electric utilities company to assess the risk of warehouse workers developing WRMSD while performing MMH tasks. For this purpose, the following objectives were defined: apply and compare ergonomic tools, namely Revised NIOSH'91 Equation, Hidalgo Model, Shoaf Model, Mital Guide, KIM, and RAMP I; suggest preventive strategies that may contribute to reduce or even eliminate the risk.

METHODOLOGY

Several visits were carried out to the warehouse to understand its operation and identify and describe the MMH activities. During the visits, photographs and movies were taken. As a result, three MMH activities were identified: material labeling, pallet preparation, and pallet checking.

Informal interviews were performed with workers and supervisors, and a questionnaire was applied to workers. This questionnaire aimed to identify the sociodemographic characteristics of the workers, the warehouse environment, and the demands of each MMH activity.

Sample Population of the Study

The sample population of this study consisted of three workers. Each worker is responsible for a specific MMH activity.

Characterization of the Tasks

a) Material Labeling

Material labeling consists of sticking a label on materials. The activity starts with picking and lifting a box (called a big box) and carrying it to a table. There, 20 small boxes are taken from the inside. Once empty, the big box is placed near the table. Then, the two materials inside each small box are labeled. After closing the small boxes, they are placed back into the big box, requiring lowering movements. During the working day, the worker labels the materials of 24 large boxes.

Regarding this activity, three tasks were analyzed: lifting, lowering, and carrying.

b) Pallet preparation

To prepare pallets, the worker moves around the warehouse on a stacker. At the stacker forklifts, a pallet is loaded with the materials of the packing list. Therefore, lifting and lowering loads is necessary to perform this activity. The stacker forklifts are at the level of the worker's waist.

Table 1. Tasks analyzed by the selected methods.

Selected Methods	Tasks
NIOSH' 91	Lifting and lowering
Hidalgo Model	Lifting
Shoaf Model	Lowering and carrying
Mital Guide	Lifting, lowering, and carrying
KIM	Lifting and carrying
RAMP I	Lifting and lowering

The worker performs this activity throughout all his working hours. On average, he prepares 15 pallets per day, performing four lifts per minute.

Two tasks were analyzed: lifting and lowering.

c) Pallet checking

Once prepared, the pallets must be checked. If the pallet does not follow the customer's order, the worker uses MMH to remove the faulty materials and place the ordered ones. After the adjustment, the final pallet is registered in the system, packed, and weighed.

The worker performs the same activity throughout his working day, with a frequency of 10 lifts per minute.

Regarding this activity, three tasks were analyzed: lifting, lowering, and carrying.

Evaluation methods

The methods used in this study were selected based on the following criteria: characteristics of each MMH activity; type of tasks they can analyze; required parameters; output provided; and duration of application.

Revised NIOSH'91 Equation, Hidalgo Model, Shoaf Model, Mital Guide, KIM, and RAMP I were selected to perform the study. Table 1 shows the methods selected and the MMH tasks they were used to analyze in this study.

The Revised NIOSH'91 Equation considers physiological, biomechanical, psychophysical, and epidemiological lifting or lowering loads. It assesses the recommended weight limit (RWL) and the lifting index (LI), which is associated with the risk of developing disorders in the lumbar region (Waters et al., 1994).

The Hidalgo Model, also known as the Comprehensive Lifting Model (CLM), is applied to lifting tasks with both hands and carried out by one or more workers. To do so, it uses two lifting indexes: the relative lifting safety index (RLSI) for a group of workers; and the personal lifting safety index (PLSI) for an individual (Hidalgo et al., 1997).

The Shoaf Model consists of four mathematical models that set the maximum recommended weight limits for lowering, carrying, pushing, and pulling tasks (Shoaf et al., 1997).

Mital Guide is a method to analyze all activities involved in MMH that are not considered by other methods. As a result, it provides the potential risk level (R) associated with each specific activity (Mital, 1999).

Table 1. Risk level to the material labelling activity.

Evaluation Method	Task		
	Lifting	**Lowering**	**Carrying**
NIOSH' 91	Medium	Medium	-
Hidalgo Model	Low	-	-
Shoaf Model	-	Low	Very low
Mital Guide	Low	Low	Low
KIM	Medium	Medium	Low
RAMP I	Low	Low	-

KIM assesses the risk of carrying out MMH activities that involve lifting, holding, and carrying tasks. It considers biomechanical, physiological, and psychophysical criteria. The method provides two application guides: KIM-LHC (lifting, lowering, holding, and carrying); and KIM-PP (pulling and pushing). Each task set has different key indicators associated (Steinberg, 2012). In this study, the KIM-LHC was used.

RAMP I is a checklist to identify and assess the risk factors associated with MMH activities. It considers the following risk factors: awkward and static postures; lifting/lowering and pulling/pushing tasks; repetitive tasks; reduced fatigue recovery time; hand firmness during tasks; vibration; psychosocial factors; frequency/duration of exposure; and working conditions (Lind et al., 2019).

RESULTS

Characterization of the Sample

The sample consisted of three male workers. The mean and standard deviation of its ages is 41±6 years, weight 66.3±3.4 kg, and height 171.7±4.5 cm. Each worker performs one of the analyzed MMH activities. Two workers considered the training provided by the company good enough, while the third worker did not.

Ergonomic Risk Level

After measuring the necessary parameters, the risk level was determined throughout the application of the selected methods.

Table 1 summarizes the risk level obtained by each method to the tasks analyzed in the material labeling activity. Overall, most tasks present a low-risk level.

Regarding the pallet preparation activity, the results are shown in Table 2. Both lifting and lowering activities are critical since the methods considered that the risk level is medium, high, or very high, except for RAMP I.

At last, Table 3 shows the risk level obtained by each method to the tasks analyzed in the pallets checking activity. It suggests that this is the most critical activity since most methods classify the risk level of the three tasks as high or very high.

Table 2. Risk level to the pallet preparation activity.

Evaluation Method	Task	
	Lifting	Lowering
NIOSH' 91	High	High
Hidalgo Model	Very high	-
Shoaf Model	-	Very high
Mital Guide	Medium	Medium
KIM	Medium	Medium
RAMP I	Low	Low

Table 3. Results of the methods to the pallets checking activity.

Evaluation Method	Task		
	Lifting	Lowering	Carrying
NIOSH' 91	High	High	-
Hidalgo Model	Very high	-	-
Shoaf Model	-	Very high	Very high
Mital Guide	High	High	Low
KIM	Very High	Very high	High
RAMP I	Low	Low	-

DISCUSSION

Comparing Ergonomic Risk Levels

Except for the RAMP I, the methods provide a similar risk level for each elementary task. From the six methods, RAMP I is the only one of level I. It is faster and less accurate, as evidenced by results.

The different risk levels for the same task may exist due to the differences between methods regarding the following criteria: type of tasks evaluated; input parameters; weight assigned to each risk factor; and interpretation scales.

The results match the answers given by workers to the questionnaire regarding their perception of the activities performed.

a) Material Labeling

Regarding the worker responsible for materials labeling, there is no record of musculoskeletal disorders. Instead, he classified the global activity as acceptable, reinforcing that most tasks present a low-risk level. However, concerning the repetition of movements, the worker referred to a medium level of demand, which may justify the lifting and lowering tasks present a medium risk level by some methods.

The NIOSH'91 and KIM methods can be considered more conservative and protective of workers since they present a medium risk level which is higher than the risk level provided by the other methods.

b) Pallet Preparation

The results also agree with the answers given by the worker. Despite the posture being acceptable, the strength required is classified as a medium while the repetition of movements is high. It can support that lifting and lowering tasks present a high/extremely high risk level.

The Hidalgo Model and the Shoaf Model seem the most conservative and protective methods since they present a higher risk level than the other methods.

c) Pallet Checking

The results also confirm the answers given by the worker. First, he classifies the posture throughout the working day as acceptable, except for the trunk, which is not acceptable. He considers the required strength high, particularly in the torso and shoulders region. In turn, the repetition of movements is extreme in the trunk and shoulders and high in the neck and wrists.

As to the pallet preparation activity, the Hidalgo Model and the Shoaf Model are the most conservative and protective methods for the worker as they present a higher risk level.

The comparison of results evidenced some advantages and disadvantages related to the application of each method.

The Hidalgo Model, the Shoaf Model, the Mital Guide, and the NIOSH'91 are more complex methods and should be used in the following situations: complex tasks; tasks where postures are unusual; and when detailed task information is required.

Furthermore, the Hidalgo Model and the Shoaf Model complement each other because the Shoaf Model was developed based on the Hidalgo Model. They consider environmental and individual factors, such as age and body weight. It is an advantage as it allows comparing the individual risk of workers and recommending ergonomic intervention measures adapted to each worker.

The Mital Guide is a complete method as it assesses all types of tasks: lifting, lowering, pulling, pushing, and carrying. These tasks can be performed with one or two hands, in awkward postures, and with high frequency.

On the other hand, KIM, and RAMP I are simple and fast to apply, so their use is recommended for the analysis of simple MMH tasks and the evaluation of the conditions of the workplace and the environmental conditions.

Ergonomic Interventions

Improvements were suggested based on the results. They are of three types: engineering controls, administrative controls, and additional measures.

a) Engineering Controls

In this context, the suggested measures consider the conditions in which each activity is carried out and the most significant risk factors in each activity.

In the case of labeling and checking pallets, it is recommended to raise the work surface to avoid excessive flexing of the trunk when lifting or lowering loads. For example, the forklift of a stacker can be used to place the boxes/pallets.

In the case of pallet conference activity, it would be an asset to expand the space so that the worker has more fixed points of support and can carry out his tasks with greater freedom of movement.

For all activities, it is considered relevant to bring the handled objects closer to the workers to avoid excessive flexion and rotation of the trunk.

However, despite their simplicity, the implementation of the suggested measures depends on the availability of company's financial resources.

b) Administrative Controls

The pallet preparation and the pallet checking activities present a high frequency. As the worker must meet deadlines, it is recommended to allocate more workers to carry out these activities. However, this measure may not be feasible as it implies an increase in costs for the company.

Another solution can be the rotation of workers, preferably alternating between activities with and without MMH.

Pauses for fatigue recovery are essential and indispensable throughout the working day, as they allow the maintenance of workers' productive capacity, especially in repetitive, long-lasting MMH activities that require some physical effort from the worker. Thus, it is suggested that more scheduled fatigue recovery breaks be established and that these are better distributed throughout the workday.

The education, training, and information of workers are essential to reduce risk factors associated with MMH activities. In this way, it is essential to promote actions that raise awareness of good practices in MMH tasks. In addition, the company's role is crucial to implement prevention measures and raise its workers' awareness.

c) Additional Measures

Regular monitoring of workers' health allows the early identification of symptoms of WRMSD. Therefore, it is recommended that workers who have already suffered disorders or are more prone should be allocated to tasks requiring less physical effort.

Management should also encourage the practice of physical exercise and a healthy lifestyle.

CONCLUSION

The purpose of this study was to analyze and assess the risk associated with three MMH activities daily performed in the warehouse of a Portuguese electric utilities company. The MMH activities were materials labeling, pallet preparation, and pallet checking. Thus, six evaluation methods were selected: NIOSH'91, Hidalgo Model, Shoaf Model, Mital Guide, KIM, and RAMP I.

After analyzing the results, some improvement measures were suggested considering each activity's risk factors and characteristics. Finally, it is anticipated that the future implementation of some of the proposed measures will make a difference for the company and its workers.

The present study is expected to contribute to healthier work practices and the prevention of WRMSD.

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