Ergonomics evaluation of a packaging workstation in an electric supplies industry

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The ergonomic suitability of the packaging workstation was questioned by the occupational safety and health department in an electric supplies company. Upper-limb musculoskeletal discomfort complaints were frequent among the assembly line workers. Therefore, an ergonomics evaluation was conducted to provide recommendations that would minimize health risks and improve productivity. Fourteen workers participated as subjects of the study. Data collection was done in two steps: (1) semi-structured interviews with the workers and (2) a biomechanical evaluation of manual work at the workstation. The right shoulder was identified as the most frequently affected body region among workers. Manual materials handling and repetitive work were the main task characteristics involved. Extended reach and awkward shoulder and trunk postures are required during the process. A new workstation design was proposed to minimize harmful posture which imposes constraints on workers.

Practitioner Summary: The results of the ergonomics evaluation formed the basis of recommendations for an improved packaging workstation design. It was proposed to minimize the harmful posture which imposed constraints on assembly line workers.

Keywords: ergonomics, biomechanical evaluation, workstation redesign, occupational health.

1. Introduction

Manual materials handling tasks are inherent to many different jobs in industry today. The performance of such tasks exposes workers to a variety of biomechanical hazards (NIOSH, 1997). Musculoskeletal disorders (MSDs) have a high impact on the worker's quality of life, due to problems such as pain and limitations in daily activities (Punnett, Wegman, 2004). A large amount of epidemiologic data are available and found a positive relationship between the performance of work and MSDs affecting the neck and upper limbs (Buckle, Devereux, 2002). The origin of MSDs is complex and multi-factorial. Many studies have shown that physical demand such as manual handling, repetitive and static work, non-neutral body postures and vibrations may be associated with upper-limb disorders. Psychosocial and cultural factors are also involved (Armstrong, 1986; Chaffin, Andersson, Martin, 1991; Armstrong, 1996; Muggleton, Allen, Chappell, 1999; Tulder et al., 2007).

This way, considering the complex state of the beginning and evolution of injuries, ergonomics contribute decisively towards satisfactory and adequate conditions to execute their tasks. The work-related musculoskeletal disorders (WRMD) can be reduced if workstations are designed with emphasis on user's comfort and safety (Eklund, 1997; Silverstein, Clarck, 2004). Since its origin, ergonomics has been guided towards the adaptation of work to man and intends to associate the health of the workers and the effectiveness of the work. Its effectiveness consists in resulting positive effects at workplace situations to become more appropriate for workers who operate them (Daniellou, 2007).

A workstation may be defined as a place where equipment and tools are positioned in such a convenient way that users can perform their tasks properly. But often, the industrial workstations are improperly projected in an arbitrary way, without considering design parameters or dimensions. Consequently, it results in reduced performance and productivity and increases the possibility of worker-related health risks (Corlett et al., 1982; Das, 1996; Eklund, 1997). The definition of the physical dimensions of a workstation's project is fundamentally important not only to productivity efficiency but also to the physical and mental well-being of the operator, as it has a direct influence on posture, standards and succession of work actions. An adequate workstation must minimize static posture, allow the worker to have various adequate positions throughout the day and provide a logical flow of the work process (Das et al., 1996; Eklund, 1997).
This study’s initial demand, brought by the health and safety department of an electric supplies industry, was to evaluate the risk factors present in the packaging department. Upper-limb musculoskeletal discomfort complaints, especially in the shoulder region, were frequent among the assembly line workers. Therefore, this paper describes a study involving an evaluation of a packaging workstation which provided recommendations that would minimize health risks and improve productivity.

2. Method

The investigation was conducted in the packaging sector in an electric supplies industry, located in a 2.170 m² area in Curitiba’s metropolitan area, Brazil. A total of 150 employees work in the four different assembly lines to produce 1.437 products, including switches, wall sockets, socket plugs and showers. On average, 720,000 products are packaged monthly.

Fourteen assembly line workers participated in the study. They are all women and have at least 1 year of experience in the packaging process. A baseline evaluation was performed in May 2013. Data collection was accomplished in two steps: (1) semi-structured interviews with the workers about task performance, operational difficulties and the perception of musculoskeletal discomfort; (2) biomechanical evaluation of manual work at the workstation. The postural load was measured using the Rapid Entire Body Assessment (REBA) protocol (Hignett, Mcatamney, 2000).

The work tasks were observed and recorded from two angles - sagittal and posterior planes. Each worker was filmed for short periods of 10 to 15 minutes randomly. Video segments were reviewed and evaluated by two trained researchers. This approach permits a more precise identification of the studied risk factors (Waren; Sanders, 2004). The set of resulting data from the biomechanical analysis of the activities allowed the staff to undertake the necessary modifications to bring about changes in the target work situation. The ergonomic implantation was constituted in the final phase of the intervention.

3. Results

3.1 Workstation and task description

The electric supplies’ packaging process consists of 5 main operations: it starts with the manual feeding of the products on the conveyor belt (1), which are packaged in an automatic wrapper. The packaged products are manually placed in a cardboard box by an operator (2) who then seals the box with the help of a hot melt glue gun (3). The sealed boxes are weighed, tagged (4) and placed on pallets for sending (5) (figure 1).

The configuration of the workplace allows tasks to be done in both the orthostatic position as well as seated. The bench in the evaluated workplace (1,06 x 2,07 x 0,86m) possesses light, non-reflecting formica top, with a frontal border and rounded edges. The hot melt glue gun, tool used for the closing of the boxes, is positioned in a holder 0,45 meters above the workbench. Concerning the environmental conditions, the illumination levels are found to be adequate to the nature of the activities.

The work period in the sector is of eight hours daily, with one-hour breaks for rest and eating and ten-minute breaks for a work exercise program. The system of switching tasks is done daily between two groups composed of seven production assistants each and the rotation amongst the group members is performed after each hour of work. For the definition of the work pace, a 15% tolerance is adopted concerning fatigue rate, eventual workplace absences and inevitable delays. The time of a standard cycle varies according to the products that need to be wrapped, the largest cycle is of 60 parts per minute and the smallest is of 40 parts per minute.

Extended reaches and awkward shoulder and trunk postures are required during the process. REBA score ranged from 6 (medium risk) to 10 (high risk). Non-neutral trunk postures were observed during the box storage process as workers had to bend to palletize the product packages.
Figure 1. Steps in the electric supplies' packaging process.

1. manual product feeding
2. product packaging
3. hot glue sealing
4. box weighing and labeling
5. placing boxes for shipping
3.2 Biomechanical analysis and postural load

The biomechanical evaluation of the activities showed the gestures and postures adopted by the workers and the physical strain involved. Some specific movements that could bring the risk of biomechanical overload were found in this analysis.

Manual materials handling and repetitive work were the main task characteristics involved. The right shoulder was identified as the most frequently affected body region among workers. Frontal flexing and torso rotations along with the ample dislocation of the right upper limb were identified. The hot melt glue gun sealing process resulted in right shoulder angles greater than 40° flexion and 20° abduction in sitting an standing position. The factor that seemed to influence the posture during the sealing task included the hot melt glue gun location, which caused the worker to frequently lift the device above shoulder height.

Shoulder angles greater than 60° flexion and 30° abduction were critical for workers’ musculoskeletal risk factors. The recommended shoulder abduction angle is 15° to 20° and flexion is 25° or less for prolonged work on tables (Chaffin, Andersson, Martin, 1991). The increase in overload in the structure of this area causes tendinous compression of the supraspinatus muscles and long portion of the biceps as well as instability in the posterior area of the glenoid cavity. (Hammil, Knutzen, 2000). The movement of the upper limb with the shoulder abducted between 8° and 23°, elbow with 90° and forearm and wrist in neutral positions, enables a better execution for manual labor that requires speed of execution (Grandjean, Kroemer, 1997).

Table 1 presents the main results of the REBA method protocol applied in the different steps of the packaging process of the analyzed sector.

Table 1. Results of the REBA method protocol.

<table>
<thead>
<tr>
<th>Step analyzed</th>
<th>Risk level</th>
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<tbody>
<tr>
<td>1. Collect the product in the containing box and feed the packaging conveyor belt.</td>
<td>6 (medium)</td>
</tr>
<tr>
<td>2. Insert wrapped products into the box</td>
<td>6 (medium)</td>
</tr>
<tr>
<td>3. Seal the box with the help of the hot melt glue gun</td>
<td>10 (high)</td>
</tr>
<tr>
<td>4. Weigh and label the sealed box</td>
<td>6 (medium)</td>
</tr>
<tr>
<td>5. Place the box on the pallet</td>
<td>10 (high)</td>
</tr>
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</table>

The transportation, handling and conditioning of the boxes is performed manually by the workers. The worker collects various boxes from the worktable containing wrapped products, weighing between 1 and 18 kilograms, and positions them on the wood pallet positioned at floor height (0.11 meters high). Torso frontal flexion movements above 40° associated with rotation or lateral inclination were identified. Torso frontal flexion posture is associated with lumbar disfunctions, there is a relation between the increase of flexion amplitude and the level of discomfort, as well as rotation movements which, when repeated, can become a risk factor for the back (NIOSH, 1997).

4. Specific ergonomics recommendations

Based on the analysis of the work in the packaging sector and the identification of the main biomechanical risk factors involved in the activities, a proposal for the adjustment of existing workstations was made. A project for the workstation was developed alongside the industry’s engineering team. The developed project required modifications in the workbench with geometry capable of accommodating the different percentiles and guaranteeing the necessary space for the execution of activities.

The new workstations were suitable for using either in standing position or in sitting position with adjustable chairs. The handling of objects near floor-level was considered problematic and adjustable height platforms were chosen to accommodate the operators during box storage. Another strategy adopted was the
automatization of the box sealing process with the elimination of the hot melt glue gun, previously repetitive and uncomfortable.

After the workstation reprojecting stage, a prototype was installed in the sector to determine the effects of the changes in the workers' comfort and equipment usability. It was observed that such alterations reduced the amplitude of movements considered critical and, consequently, the associated risk of developing musculoskeletal disorders. The proposed workstation would improve working posture and reduce the fatigue levels, provide flexible work height, reduce reach requirements and enhance workers' productivity. It was accepted by the engineering team, who agreed to install the new workstation with the recommended design.

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References