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Design proposal of an adjustable workstation for very short and very tall people

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Abstract

This research presents a design proposal for extremes where men and women perform similar tasks in the same workstations. Within assembly lines hydraulic presses that allow to be adjusted to different heights are used. However, at the initial workstation of the cell production, a high fixed workstation is used. In addition, workers have to handle axis of different dimensions. For example, the shortest is 50 centimeters while the longest is 90 centimeters. Medical service department has received constant complaints from workers assigned to this workstation, which reported mostly musculoskeletal discomfort in shoulders, neck and back. The objective of this research is to develop a new workstation design that allows adjusting its dimensions according to the worker´s statures and part´s sizes used in the assembly lines. Ergonomic assessment was developed applying the Muscular Fatigue Assessment (MFA) and Biomechanics analysis before and after workstation implementation. The MFA method shows very high levels of ergonomic risk on shoulders, neck, back, and hands. While the biomechanical evaluation shows overload on shoulder (321%), elbow (490%), L5/S1 (518%), and hip (118%). A workstation that reduces risk levels from very high to medium is designed and also eliminates overloading in shoulder and ankle. This is confirmed by the methods of assessment after implementation of the new design workstation.

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1. Introduction

The lack of planning in the design of workstations causes that workers have to adapt to work conditions that were not designed for them. One of the ergonomics principles says: "the hands should not be placed above the heart; especially exerting significant force [1]. According to Nussbaum [2], make significant efforts with arms raised above the shoulders can cause discomfort and musculoskeletal injuries and muscle fatigue in the upper limbs. High frequencies of musculoskeletal discomfort have been reported among workers in areas of automotive parts assembly [3]. Therefore, postures, as the mentioned, should be removed from the working methods.

This article presents a case study where postures of a task assembly of CV Joints are analysed. In this task, various components are placed on the top of the part known as "axis". The main part is called "boot". The secondary parts are “straps” to hold the boot. The length of the axis is variable and depends on two factors: 1) if the CV Joint will be placed on the right or left side of the car, and 2) the type of car where the piece will be used, i.e., larger cars needs larger CV Joints. The shortest axis is 50 cm whereas the longest axis is 90 cm. The length difference causes that the high, where the axis is placed to be assembled, is different. Furthermore, the workstation where the assembly is performed does not allow the height adjustment. Therefore, operators must adopt extreme postures, such as hyperextension of shoulder and neck to place the components in the CV Joint, especially when the shortest workers (stature of 1480 mm) places pieces on longer axis. An example of this is shown in figure 1.

Fig. 1. Two examples of components placement in the first workstation.

All assembly lines in the company have been configured as U-lines production, All U-lines include four task: 1) place boot and straps, 2) add a second axis, 3) placed grease, and 4) the finished CV Joint is weighed and placed on the pallet. All U-lines include the same workstation at the beginning of the assembly process. The task at this workstation includes three principal subtasks: 1) take the axis from the cart and place it in the assembly workstation, 2) place the components (boots and straps) on the axis, and 3) place the axis in the next workstation. The cycle time is 30 ±5 seconds. The length of the work shift is ten hours and approximately 1000 CV joints are assembled in each cell production. The medical service department has received constant complaints from workers assigned to this workstation that have reported mostly musculoskeletal discomfort in shoulders, neck and back. The objectives are:

- Develop a new workstation design that allows adjusting its dimensions according to the worker´s statures and part´s sizes used in the assembly lines.
- The workstation must perform the height change quickly.

2. Methodology

2.1. Study design

A cross-sectional, exploratory, and prospective study is presented.

2.2. Sample

Because shorter workers are having more trouble performing assembly tasks, the ergonomic analysis was performed to the shorter worker. To determine the design specifications of the workstation, anthropometric data of 272 workers (men and women) were considered to determine the dimensions of the new workstation.

2.3. Ergonomic evaluation

The ergonomic evaluation was conducted in two phases. In first, the original task where the workstation that does not allow height adjustment used was evaluated. In the second, the task was assessed after implementing the new workstation that allows adjusting the height. The ergonomic evaluation was performed using two different methods, the Muscular fatigue Assessment (MFA) [4, 5] and Biomechanical Evaluation [6] using the web page www.ergonautas.upv.es. Next, both methods are described.

2.3.1. Muscle Fatigue Analysis (MFA)

The Muscle Fatigue Analysis was proposed by Rodgers [4,5] as a means to assess the amount of fatigue that accumulates in muscles during various work patterns within 5 minutes of work. The hypothesis was that a rapidly fatiguing muscle is more susceptible to injury and inflammation. With this in mind, if fatigue can be minimized, so should injuries and illnesses of the active muscles. This method for job analysis is most appropriate to evaluate the risk for fatigue accumulation in tasks that are performed for an hour or more and where awkward postures or frequent exertions are present. Based on the risk of fatigue, a Priority for Change can be assigned to the task. Using a task data sheet for each body region, assess the three job risk factors by assigning each factor a rating by category. The task data sheet provides a format for this process. Descriptions of Effort Levels for the different body regions, Continuous (single) Effort Duration and Effort Frequency are provided on the data collection form. Within a body region, once an Effort Level is chosen to represent the task, the assignment of Continuous Effort Time and Efforts per Minute should be associated with the chosen effort. Notes: If the effort level is high enough that most workers cannot accomplish it, if the continuous effort duration is greater than 30 sec, or if the frequency is greater than 15 / min, then there is sufficient reason to assign a Very High priority for change. The Priority for Change is found by locating the combination of scores in the various categories in the table on task identification data sheet. Note: A combination of 3 and 3 for Duration and Frequency is not possible. The table provides an indication of relative risk for fatigue within a category. The earlier the combination of categories is in the list the lower the fatigue should be (i.e., it is better).

2.3.2. Biomechanical analysis (Available at www.ergonautas.upv.es)

Musculoskeletal load due to physical injuries often have a common origin: the overload of body structures (joints, tendons and tendon sheaths, ligaments, muscles, etc.) due to repeated and/or excessive stress levels in inadequate postures. Although many ergonomics evaluation methods address the issue of assessing the level of risk of making efforts, the application of biomechanics will allow get more and detailed data about specific risk assessment procedures. To assess an effort in a particular position that may overload some musculoskeletal structure is a complex task. Biomechanics addresses this task by drawing an analogy between the human body and a composite of levers and pulleys machine. Thus, it can be considered that a joint is the fulcrum of a lever (a long bone) driven by a muscle (the power) to overcome resistance (the weight of the members and the sustained load). Setting this analogy is possible to apply physical laws to determine whether there articular overloads during execution of an effort.

The stress to which it is subjected to the joint is, on the one hand, due to the support of the weight of the limbs and the load, and moreover, when these forces cause on the joint and must be defeated to maintain posture. Knowing that the moment of a force about a point is the vector cross product of force by the vector distance from point to point of application of force and applying the equilibrium equations, it is possible to determine the moment and reaction force in the joint. The application of the described model for the evaluation of efforts in different joints is a procedure that can be complex without the support of a software tool. The calculation tool offered by ergonautas.com allows physics calculations and application of the model from the input data, providing the following results: the level of effort in each joint, the maximum recommended load, the percentage of protected population, besides the postural stability, the ability to slip and fall of the worker under the supported loads.

To perform the calculations should be collected a data set about the task: gender worker, height, weight, angles of the body segments in the position analysed, weight sustained load or force exerted, if the load is held with one or two hands, time during which efforts are made, and frequency efforts. The load level joint is expressed on a scale of reason to start at zero. If a joint obtained a higher level of 100% load, the work done may cause risk of injuries to the worker.

3. Results

3.1. Ergonomic evaluation before workstation design

The ergonomic evaluation with the MFA method is shown in Table 1.

Table 1. Ergonomics assessment of current task conditions.

Region	Neck	Shoulders	Back	Arms/elbows	Hands, Fingers/Wrists	Ankles/feet/Toes
Priority	High	High	High	High	Moderate	Low

In both methods (MFA and Biomechanical analysis) high level of risk is obtained on shoulder, neck, and back. The MFA method considered a high priority level of change in neck, wrist, elbow, and arm. The Biomechanical Analysis considers that there is overload in shoulders, elbows, joint L5/S1, and hip. Therefore, changes in the workstation and/or the working method should be performed as soon as possible. The biomechanical analysis is shown in figure 2.

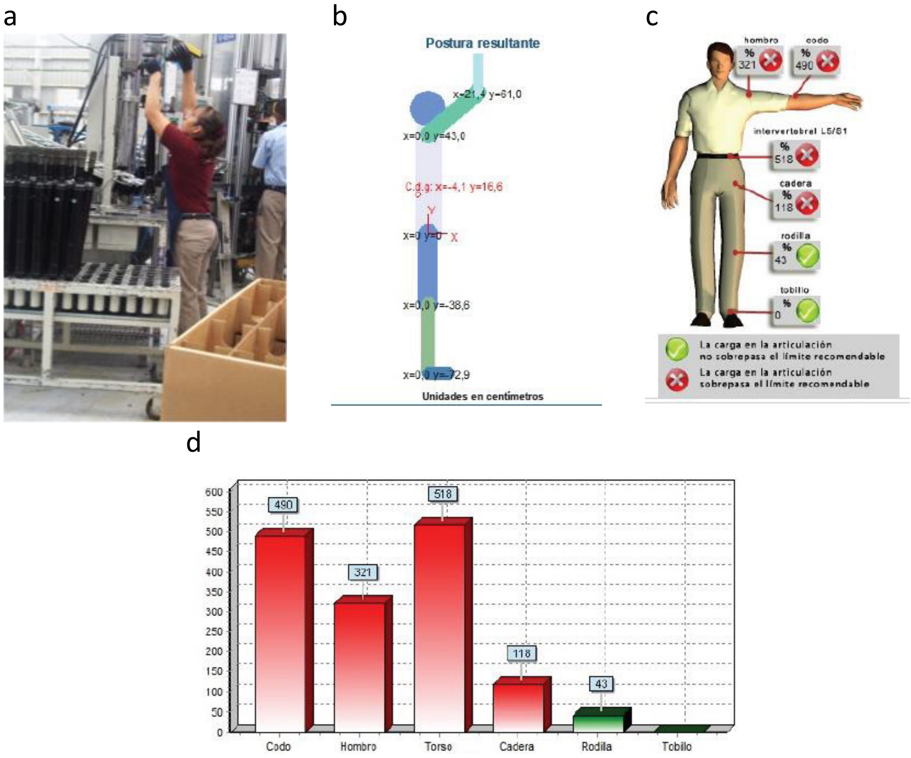

Fig. 2. Biomechanical analysis of current task conditions. a) Current task; b) posture used in biomechanical analysis; c) load analysis on joints; and d) bar graph of the load analysis on joints.

3.2. Workstation design

In order to develop the proposed design of the new workstation, body dimensions of workers were considered. The medical service provided anthropometric data of the stature of all company employees. The dimension "elbow height" was estimated using the predictor model proposed by Hernandez [7]. This dimension was considered as the basis for the new workstation design. Because the workstation must adjust its height to very short and very tall people, two highs were determined: the minimum height to the shortest worker and the maximum height to the tallest worker. A comfort distance of 200 mm was added to allow better adjust to the workers. Table 2 shows the calculations performed.

Table 2. Anthropometric calculations

Stature	Predictor model	Elbow heigh	Comfort distance	Work high
Smallest worker: 1480 (women)	Y=0.6747(estature)-64.573	933.98 mm	200 mm	Min: 1133 mm
Highest worker: 1850 (men)	Y=0.5535(estature)+144.96	1168.93 mm	200 mm	Max: 1318 mm

Based on the calculated dimensions and considering the dimensions of the parts used in the assembly task, three pieces were designed to allow adjustment of the new workstation dimensions. Those are shown in figure 3.

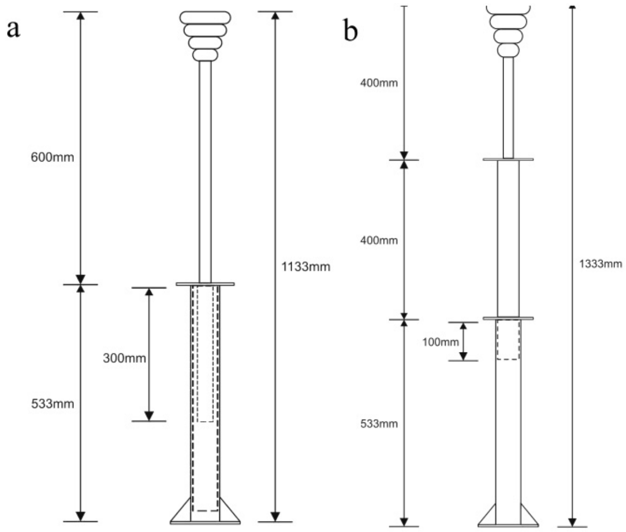

Fig. 3. a) Base, b) Piece to assembly the shortest axis, c) Piece to assembly the largest axis.

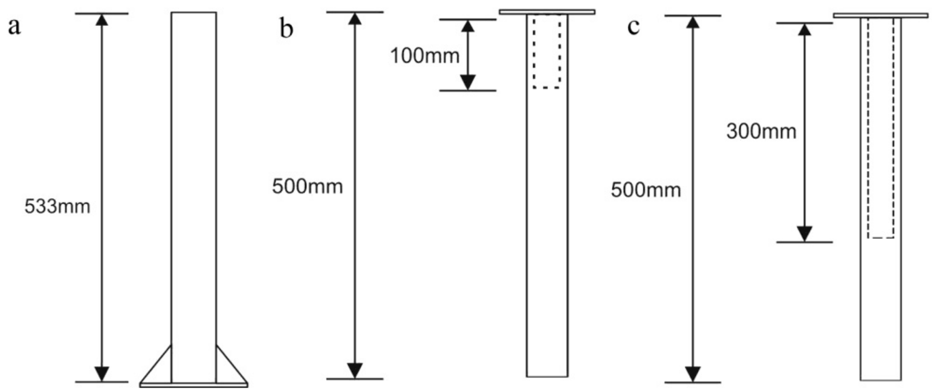

Fig. 4. a) Design for the longest axis and the shortest worker, b) Design for the shortest axis and the tallest worker.

The assembly of the new workstation is shown in figure 4. Two design proposals to assembly the longest axis and the shortest axis considering the statures of very short and very high people were included in the design.

3.3. Ergonomic evaluation after workstation design

The ergonomic evaluation after workstation design with the MFA method can be seen in Table 3.

Table 3. Ergonomics assessment after new workstation implementation.

Region	Neck	Shoulders	Back	Arms/elbows	Hands, Fingers/Wrists	Ankles/feet/Toes
Priority	Low	Moderate	Low	Moderate	Moderate	Low

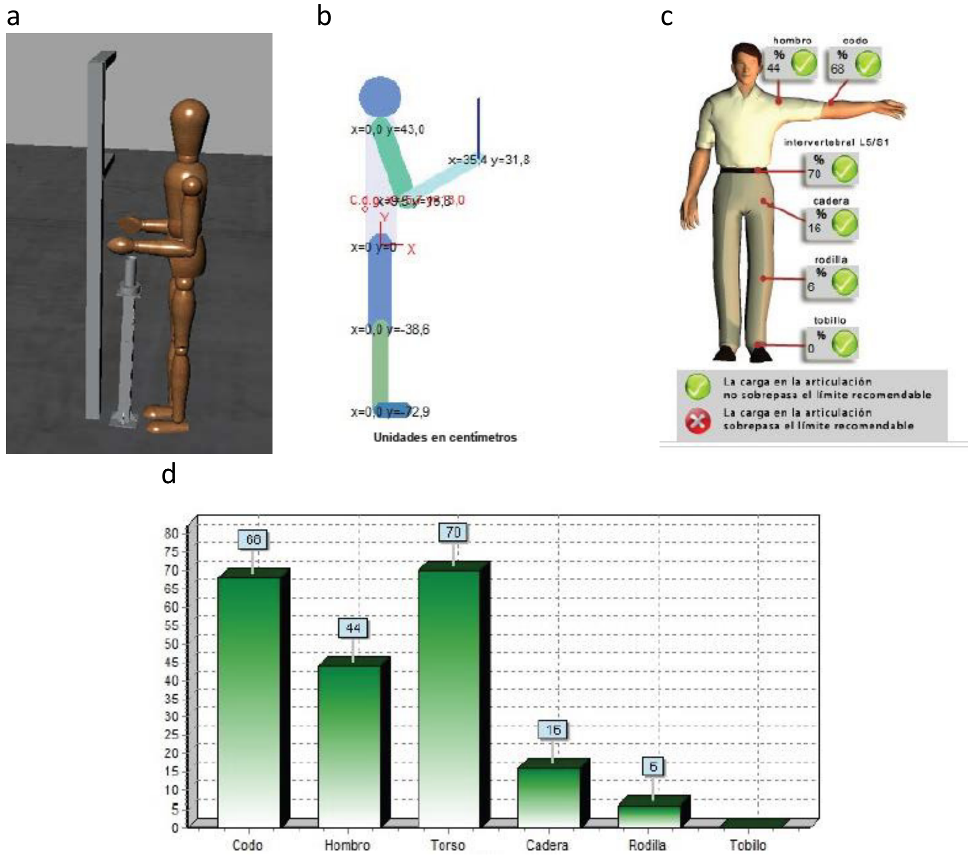

Fig. 5. Biomechanical analysis after new workstation implementation. a) simulated task using the new workstation design; b) posture used in biomechanical analysis; c) load on joints; and d) bar graph of the load on joints.

The biomechanical analysis is shown in figure 5.

The ergonomic evaluation after implementation of the new workstation results in low levels of priority (neck, back, and ankles/feet/toes) and moderate (shoulders, arms/elbows, and hand/fingers/wrists) after MFA using the method. The biomechanical analysis considers that there is no overload of analyzed joints.

4. Conclusion

In the case presented here is shown as, due to the data analysis of medical service department, a sample solution that reduces significantly the levels of muscle fatigue and overload on the joints was found. Because the solution developed is not definitive, it should be improved. However, the new workstation helps to the workers to have less ergonomic risk and keep the pace of work requested by the company.

It is desirable that companies spend resources to design better workstations that can be used by most or all workers regardless of their anthropometric composition. Forcing workers to adapt to jobs that are not designed for their physical and/or mental characteristics can result short-, medium- or long-term, serious injury to the workers affecting significantly productivity of the companies, especially when a worker with a high degree of training is injured and must stop working.

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