Chapter

How Poor Workstation Design Causes Musculoskeletal Disorders: Research from QOC Matrix the Workers' Voice

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Abstract

An ergonomic intervention method based on QOC Matrix the workers' voice was implemented in a study case. The diagnosis and analysis developed are used in improvement proposals for workstation redesign. The workers' voice resulting from reports of the employee' complaints and symptomatology was the base for a standardized method that comprises: (a) QOC questionnaire application, (b) risk factor categorization, (c) determination of unsafe and unhealthy ergonomic metrics, (d) figuring out the task content impact in the workers' body, and (e) work system diagnosis. Since workers' voice, the risk identification made included: (1) the task content linked to work method: repetitiveness associated with the sensor activation using the fingers and the repetitive movements include twist and the stretch of wrist, (2) workplace design regarding container height and injuries caused in wrists and elbows due to hits, (3) task developed regarding risk time exposition and workers position, and (4) workplace design regards to housing collector distance from filling area linked to workers position adopted for reach bags. Improvements included redesign of the workstation with a system of 90° exit discharge curve, one elevation system, and a photoelectric sensor in filling nozzle for automatic filling. As an improvement result, the activity called bags provision was eliminated from the task.

Keywords: ergonomics, musculoskeletal disorders, ergonomic intervention, assessment, risk factors

1. Introduction

Physical and ergonomic risks cause musculoskeletal disorders (MSDs). Physical risks are external loads associated with long periods of exposure during tasks performed. The external loads are caused by awkward postures, manual material handling,

repetitive motion, and force exerted. All of them are known as ergonomic risk factors (ERFs), which impact on health and well-being of workers [1, 2]. Ergonomics comprises a set of techniques directed to adequacy of the work to the people, optimizing human well-being and performing the overall system [3, 4]. Elements of work system are: workplace, tasks performed, tools manipulation, products and materials manipulation, work organization, and work environment [5, 6]. During the interaction of a person with the work system, unsafe and unhealthy elements must be changed or redesigned. The Mexican Ministry of Labor and Social Safety (STPS) defines that if one of this interaction is incorrectly designed, the work task requirements will become ERFs that can lead to musculoskeletal disorders and occupational illness [7].

In Mexico, the real number of musculoskeletal disorders (MSDs) developed by workers is unknown due to three main causes: (1) workers are afraid of being dismissed by employers if they report symptoms of illness [8], (2) employers have historically evaded the law and they have not usually implemented safety and health standards in workplaces [9], and (3) authorities have improperly followed up safety inspections. Therefore, the negligence triggered apathy to assure abatement of risk conditions and has caused omissions, contributing to under-reporting risk conditions and work accidents [10]. Despite under-reporting risk factors, the concern of Mexican authority is the upward trend of developing MSDs (within the industrial and service sectors), as established in the First Forum on Safety and Health at Work, carried out in Mexico City in August 2015, where the ergonomic risk factors are identified as a main problem due to their impact on workers' health and their economic costs [11]. The increase in cases (73% on average) in 8 years (2009–2017), informed by the Mexican Institute of Social Safety (IMSS) [12, 13], reported a cumulative total of 20,523 cases, identifying dorsopathies as the most prevalent work disease with 6752 cases (32.9%) followed by enthesopathies with 3490 cases (17.01%) and carpal tunnel syndrome with 3280 cases (15.9%) (**Figure 1**).

To abate this health problem, the government has issued a mandatory rule called Federal Rule for Safety and Health at Work (Reglamento Federal de Seguridad y Salud en el Trabajo) [14]. It includes employer obligations to find, to report, and to reduce ergonomic risks presented inside facilities. Thus, the question is: how

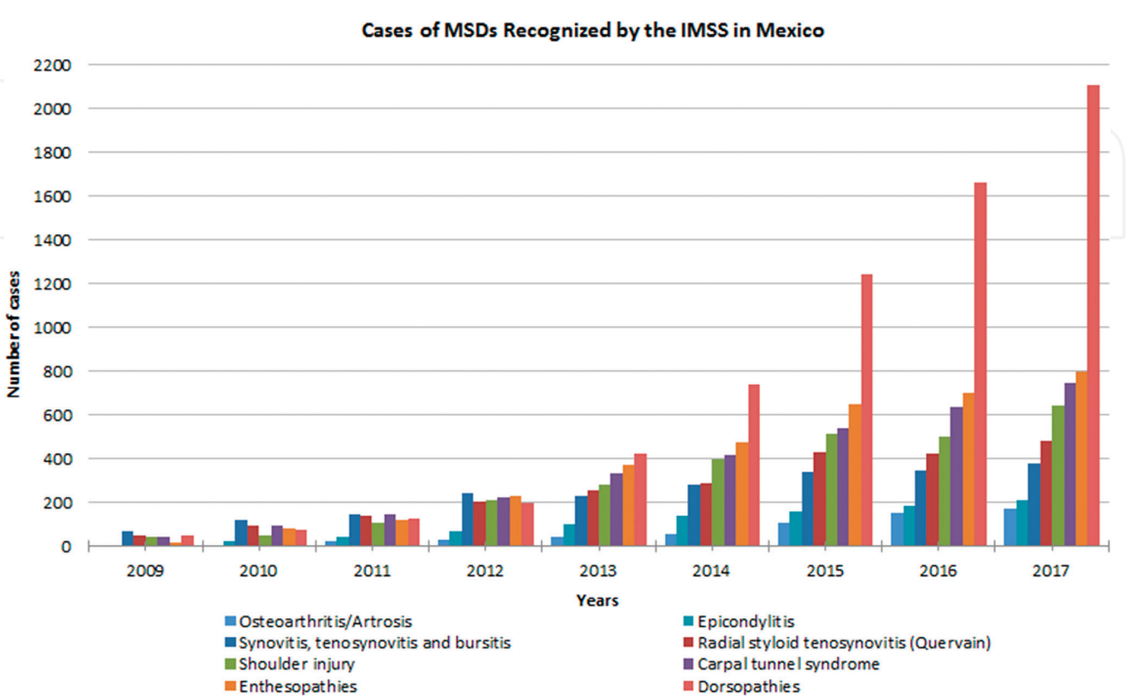

Figure 1.
Cases of MSDs reported by the IMSS during years 2009–2017 are organized according to the nature of injury.

employers can follow the law taking in to count that (a) ergonomic aspects are ignored for a long time, (b) ergonomic risks are seldom identified, and (c) an ergonomic intervention is not commonly carried out.

Based on the latter, it is important to define that an ergonomic intervention includes a diagnosis and analysis about the work system, which results in making improvement proposals [15]. If a proposal is carried out (elimination of ergonomic risk factors), a reduction of reports from employees' complaints must be observed.

In this chapter, an ergonomic intervention method based on QOC Matrix the workers' voice is carried out in a study case, the diagnosis and analysis developed were used to propose a workstation redesign as improvement proposals. Reports of the employees' complaints and symptomatology suffered represent the *workers' voice*. Improvement proposal should be standardized, to warranty workers' complaint reduction. Methods include: (a) QOC questionnaire application, (b) risk factor categorization, (c) determination of unsafe and unhealthy ergonomic metrics, (d) figuring out the task content impact in the workers' body, and (e) work system diagnosis.

2. Methods and tools

2.1 QOC Matrix the workers' voice ($_{QOC}$MWV)

QOC Matrix-the workers' voice ($_{QOC}$MWV) [16, 17] is an interactive ©Microsoft Excel spreadsheet. It uses decision support system (DSS) [18] that helps people to apply ergonomic parameters to identify and categorize the risk factors and fix them through ergonomic intervention.

It involves a *questionnaire* that encloses in each question *criteria* from: ergonomic ISO standards, Mexican safety and health standards, OSHA and NIOSH recommendations, among others used as evaluation parameters. During an ergonomic risk assessment, workers have to choose the *option* that answer questions according to their perception about workstation and tasks developed; the results got are called *workers' voice*.

The questionnaire was organized in to five sections: (1) work area with two subdivisions: (a) workplace design and (b) task content, (2) manual material handling, (3) work organization, (4) work environment, and (5) psychosocial aspects. Metrics for intervention and specific risk factors are obtained because of its implementation. Metrics are proportions (%) that define the level of risk. Specific risk factors are dimensional relations worker-workstation, repetitiveness, load manipulated, and exposition time. The results are represented in Pareto charts.

2.2 Pareto charts

Pareto chart is a frequency distribution (or histogram). It was used for arranging risk factors by category. Pareto method and rules of 70/30 (Pareto principle) [19] can identify crucial areas from the intervention standpoint. When the Pareto principle is determined, the common effect of workers' answers that a relative few of the contributors (risk factors)—the vital few—accounts for the bulk of the effect (MSDs). The vital few identification is easier when the tabular data are presented in graphic form that encloses the next main elements [20]:

1. Risk factors to the total effect, ranked by the magnitude of their contribution

2. Magnitude of each risk factor is expressed as a percentage of total

3. Sum of magnitude of all contributors is expressed as a total percentage.

3. Case study

The $_{QOC}$MWV survey was implemented in three automatic high-speed lines designed for filling dialysis bags with a liquid mixture and produces 110,000 bags daily. The production time comprised three shifts of 8 h, with 16 operators in each line by shift. Activities were developed on standing posture. Workers took a lunch time of 0.5 h, in the middle of the work period. Ergonomic risk factors like manual material handling, repetitive movements, awkward postures, and force exerted were identified as a part of task performance. In **Table 1**, the work method developed by a worker is presented.

Because of exceeding permissible exposure limits by operators, the company has received a preaction for probable occupational disease ST-9 (official document) issued by the IMSS, to the medical treatment for work-related injuries and diseases. In a preanalysis, the following percentage of cases suffered by workers was found: 30% epicondylitis, 20% hand tendinitis, and 10% shoulder injury.

Activity	Left hand	Right hand
Bags provision (92 × shift) 	1. Reach housing collector to grasp 30–50 bags (the amount of grasped bags depends on worker skills) 2. Move the bags to the container 3. Arrange the bags and put in right position 4. Release the bags in container	1. Wait for bags 2. Hold the bags 3. Hold the bags 4. Release the bags
Fill bag (4584 bags per person) 	1. Take bag no. 1 from container 2. Position the bag pipe under filling spout 3. Hold bag with fingers 4. Hold bag with fingers until filling starts 5. Wait 6. Hold filled bag with fingers 7. Position filled bag with fingers 8. Take bag no. 2 from container	1. Put up in filling spout 2. Activate filling with the little finger 3. Take balloon port from container 4. Soak balloon port in glue 5. Position balloon port 6. Put balloon port in filled bag 7. Release filled bag

Table 1.
Work method used to fill dialysis bag.

4. Method for ergonomic intervention

The method used for implementing the ergonomic intervention was applied as follows:

Step 1: the workers' voice was collected through applying QOC questionnaires.

Step 2: the results of workers' voice were the base to categorize ergonomic risk factors, through a Pareto chart in three cases of intervention:

1. effects caused in workplace by unsafe and unhealthy elements,

2. effects caused in work task by unsafe and unhealthy elements,

3. task content impacts in the workers' body.

Step 3: once the risk factors were identified, an ergonomic work system diagnosis was carried out.

Step 4: project improvements were determined to abate risk factors identified.

5. Results and discussions

5.1 Work system diagnosis

Questionnaire $_{QOC}$MWV was applied to 48 operators and three supervisors from each shift. (In **Figure 2**, an example of part of assessment is shown.) Workers tested the work system, and the task was chosen from options. Options were represented

WORKERS' VOICE						
N= UNCONFORTABLE		N= NO				
NT= NOT AT ALL CONFORTABLE		NT= NOT AT ALL = NO DEL TODO				
S= CONFORTABLE		S= YES = SI				
WORKERS		1	2	3	4	5
No.	QUESTIONS					
1. WORK AREA						
1.1 WORK PLACE DESIGN						
1	Does the work area suitable to the operator according to his/her physical conditions?	N	N	N	NT	N
2	Do the head and hips movements easy and safety?	NT	N	NT	NT	S
3	Do the movements of the feet in comfortable position?	NT	NT	N	NT	S
4	There are some mechanisms which allowed to manipulate higher loads (more than 50kg like hoist/ platforms, etc)?	N	N	N	N	N
1.2 TASK CONTENT						
5	Does the work task not have repetitive movements which can cause fatigue in arms, shoulders, forearm and wrists?	N	N	N	N	N
6	Does manual manipulation not have repetitive movements and does no require a major force to lift a load in which involves distance and time that causes stress on the trunk and lower limbs?	N	N	N	N	N
7	Do the machinery and/or process not determine the rhythm of work?	S	S	S	S	S
8	Do the handles or slings help to manipulate the materials in easy way and they are well located?	N	NT	NT	N	S
2. MATERIALS						
9	Is there a place assigned for each tool, machinery and row material?	S	S	S	S	S
10	Is the process free of machinery or tools vibrations?	N	N	N	N	N
11	Does product manipulated at room temperature?	N	N	N	N	N
3. WORK ORGANIZATION						
12	Were you trained to perform the task?	S	S	S	S	S
13	Is there a procedure in which specifies the ergonomic requirements of the workstation and tasks?	N	N	N	N	N
14	Is there a work method that establishes unsafe and unhealthy activities?	N	N	N	N	N
15	Do you periodically receive medical review inside facility?	S	S	S	S	S
16	Do you practice labor gymnastics during the task?	N	N	N	N	N
17	Does the task not require activities such as planning, inspecting or correcting?	S	S	S	S	S
18	Do you finish you work on time and you do not require over time?	S	S	S	S	S
19	Define you task as follows: Y= light, NT=moderate, N=heavy	N	N	N	N	NT
4. WORK ENVIRONMENT						
20	The lighting can enhance task performance allows observing the details of the product/material and does not generate shadows?	NT	NT	N	N	S
21	Does the work area clean and in optimal conditions to perform the demanded task?	S	S	NT	S	S
22	Does the noise allow speaking without shouting?	N	N	N	N	N
24	Do you consider the temperature of work place is comfortable to work?	N	NT	NT	NT	Y
5. PSYCOSOCIAL ASPECTS						
25	Do you not do high speed activities or activities that need a lot concentration?	N	N	N	N	N
26	Do you feel motivated at work and without pressure and stress?	S	S	NT	N	S

Figure 2.
Example of a questionnaire applied using the QOC matrix—the workers' voice.

Symbol	Description	Color	Risk associated
S = Yes	Comfortable	Green	No risk
NT = Not at all	Not at all comfortable	Yellow	Risk
N = No	Uncomfortable	Red	High risk

Table 2.
Options chosen during the evaluation using $_{QOC}$MWV.

by letters that symbolized a level of comfort, for example, "S" for comfortable. Each option was associated with a color to show the risk [21], as shown in **Table 2**.

In Mexico, the workforce is people who have basic studies in the best case; therefore, workers' training is difficult in ergonomics issues. Therefore, the survey made to the workers focuses in their filings, complaints, and motivations [16]. The matrix results were organized through three Pareto chart.

5.2 Categorization of ergonomic risk factors

5.2.1 Unsafe elements of work system components

Figure 3 shows the work system elements evaluated. According to Pareto principle, the cumulated frequency symbolizes "the vital few" (see Section 2.2). Therefore, this percentage was considered as the workers' voice index. Unfortunately, the Pareto principle was not presented in the first chart (rule of 70/30) as is observed in **Figure 3**, due to which there were small differences between opinions about unsafe and unhealthy work system elements. Workplace and task content received 18 complaints, each one representing only 37% of cumulate frequency, and materials handling and psychosocial factors received 17 complaints, each one representing only 35.06% of cumulate frequency, the 70% was to reach until the fourth bar and not in the first three bars, as established by the Pareto rule. Hence, there was no main work system element identified as workers' voice to be improved during the intervention.

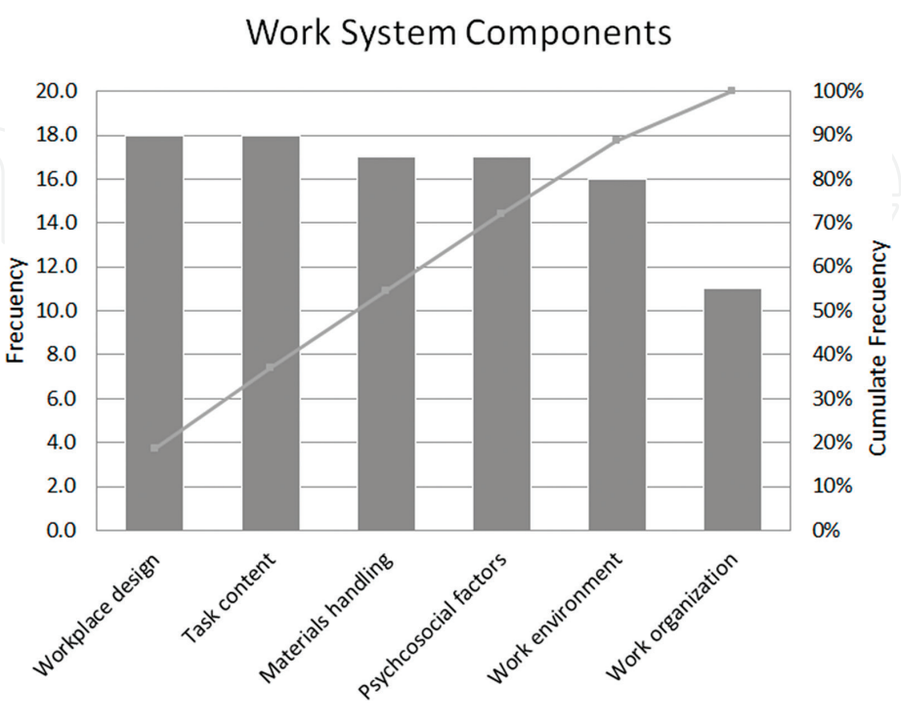

Figure 3.
Pareto chart resulted from work system components evaluation.

The unusual behavior got in the Pareto chart was explained by the workers' complaints in this manner; *workplace design:* the workers suffered continuous little hits in wrists and elbows, caused by the container height and the housing collector distance from filling area, arm overstretching in the moment of taking set bags, and awkward position during the filling bag process. *Task content and materials handling:* as the speed of line was too fast, and they have to handle huge materials quickly and exhaustively. Aspects were confirmed with the results got in the second Pareto chart.

5.2.2 Unsafe and unhealthy ergonomic metrics

In the second Pareto chart, the ergonomic metrics about the task were evaluated, see **Figure 4**. The chart bars symbolize the task metrics, which was assessed by the $_{QOC}$MWV by comparing the process parameters vs. international standards. In this chart, the Pareto principle was more clearly presented (rule of 70/30). Unfavorable environment received 23 complaints, repetitiveness received 20 complaints, and body position received 19, thus representing only 64% of cumulate frequency, close to 70%. Hence, unfavorable environment, repetitiveness, and body position were identified as workers voice to be improved during the intervention.

The chart results due to the unfavorable environment of the task were tied with the workplace design, and then at least 41 opinions from the 48 workers had complaints about work place design; in the same way, task content was linked with repetitiveness; then, at least 40 from the 48 workers had complaints about task content. Thus, *workplace design* and *task content* were identified as *workers' voice*.

5.2.3 How task content impacts workers´ body

In the third Pareto chart, the task content impact in the workers' body was assessed. The chart bars that represent the human body parts were exposed to injury due to ergonomic hazards and unsafe conditions. Once again, the Pareto principle was not presented in the third chart (rule of 70/30) as observed in **Figure 5**. However, the upper limbs (as a whole) were identified as affected by the repetitive works developed.

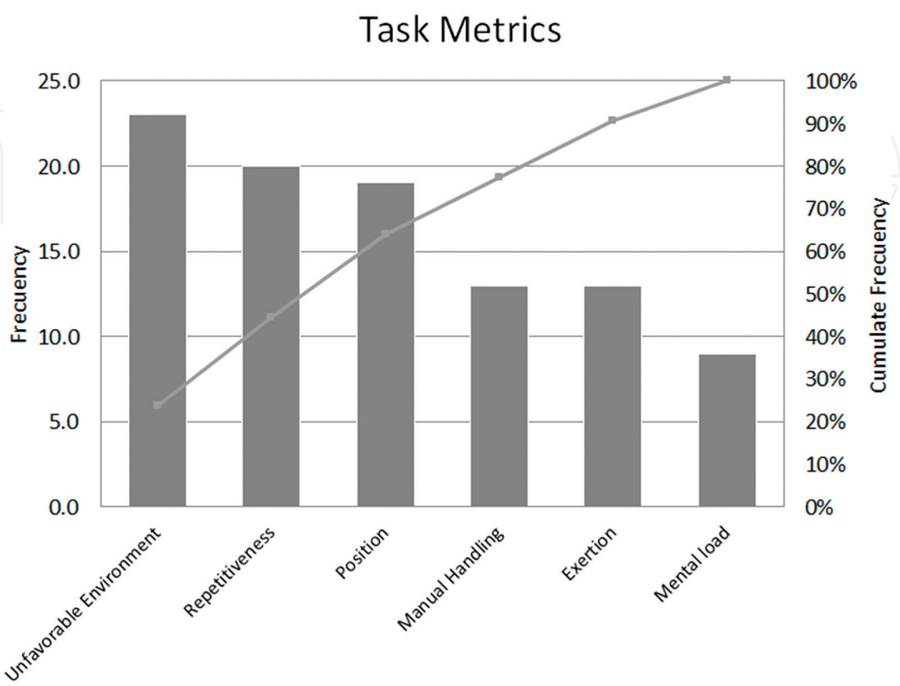

Figure 4.
Pareto chart resulted from task metrics identified as risk.

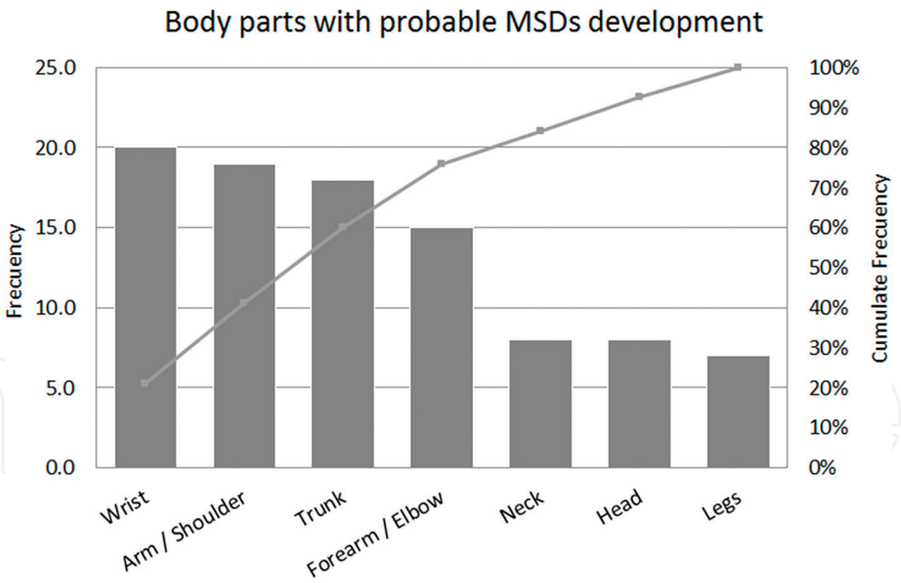

Figure 5.
Pareto chart representation of body parts identified that will probably be injured.

5.3 Diagnosis to determine the incompliances regarding ergonomic rules

The results of the diagnosis about incompliance of ergonomic rules inside the work system are mentioned below.

5.3.1 Identification of risks

1. The task content about work method:
    a. Repetitiveness associated with the sensor activation using the fingers
    b. The repetitive movements include twist and the stretch of wrist
2. Workplace design regards to container height:
    a. Injuries associated with wrists and elbows hits
3. Task content regards to task duration about workers' position
4. Workplace design regards to housing collector distance from filling area about workers' position adopted for reach bags.

5.3.2 Symptoms found

1. Wrist pain and swelling caused by repetitive little hits
2. Elbow pain and swelling caused by repetitive little hits
3. Shoulder pain regarding arm overstretching position adopted to reach bags
4. Back pain regarding task duration and workers' position adopted to reach bags.

5.4 Improving proposal work station redesign

5.4.1 Transport system of bags

In order to eliminate the 92 repeated overstretching positions taken by the workers during task performance (**Table 1**), redesign of the workstation was proposed (see **Figure 6**). Improving proposal included a transport system of a 90° exit discharge curve, which will position in the right way the bags are directed into the base container. Regarding poor design of container height and the distance between the collector and the worker, a slide elevator system was added, which included an optical sensor with two main functions. First one consists in detecting each bag to move the elevator system down when each bag is deposited in the container base, the second one refers to moving up the container base added to the elevator system when a determinate quantity of bags is counted, allowing the workers to reach without additional efforts to the bags. Additionally, a synchronization of the conveyor system was suggested, improving the productivity and decreasing the overwork driving to the human factor.

5.4.2 Photoelectric sensor implementation in filling nozzle

For reducing repetitiveness in the activation sensor (**Table 1**) during filling bag (right hand), a photoelectric sensor was implemented. It will automatically activate the filling nozzle. This implementation allowed eradicating the twist and stretch movements generated at wrist (see **Figure 7**).

5.4.3 Work method improvements

After ergonomic intervention, "bags provision" activity (**Table 1**) was eliminated, as well as the activation of filling with right-hand little finger. The work method resulting is shown in **Table 3**.

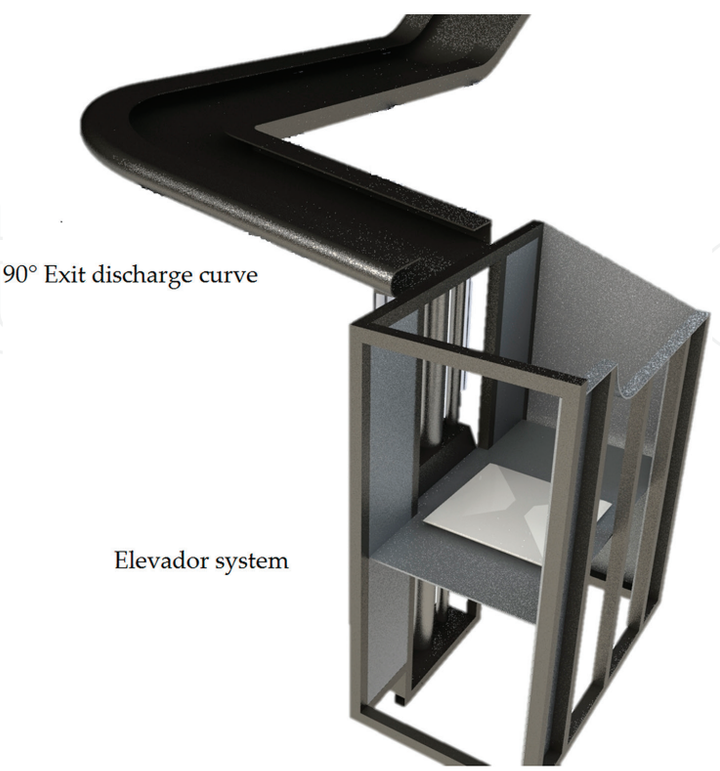

Figure 6.
Workstation proposed redesign. It includes a system transport of 90° exit discharge curve and an elevation system.

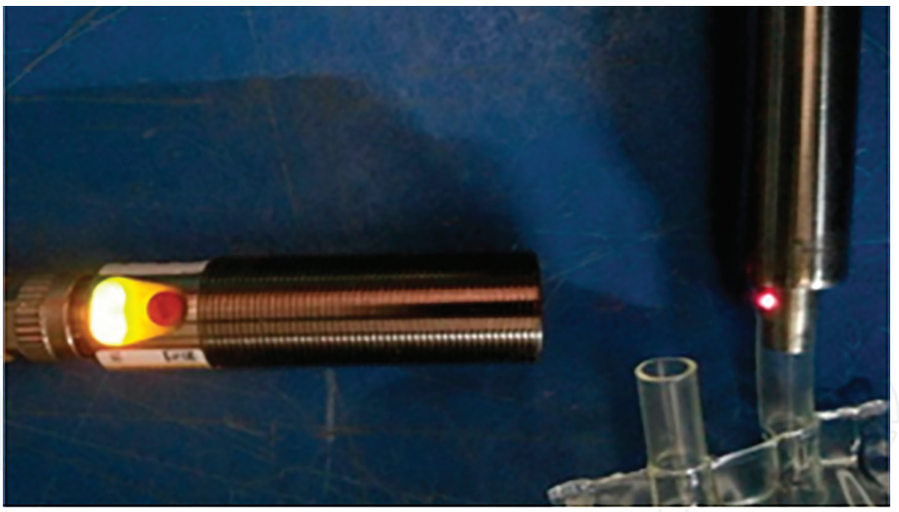

Figure 7.
Photoelectric sensor in filling nozzle for automatic filling.

Activity	Left hand	Right hand
Fill bag (5000 bags per person) 	1. Take bag no. 1 from container 2. Position bag under filling spout 3. Hold bag with fingers 4. Hold bag with fingers until filling starts 5. Wait 6. Hold filled bag with fingers 7. Take bag no. 2 from container	8. Put up in filling spout 9. Take balloon port from container 10. Soak balloon port in glue 11. Position balloon port 12. Put balloon port in filled bag 13. Release filled bag

Table 3.
New work method for the task filling dialysis bag.

6. Conclusions

The assessment and diagnosis method based on $_{QOC}$MWV was developed and implemented, with the objective of improving the labor relationship, between workers and employers as well as their working conditions. The standardized method allows obtaining relevant diagnosis about hazards and ergonomic risks factors present in the work system, which leads to musculoskeletal disorders. The study shows that the $_{QOC}$MWV: (a) improves the worker-employer understanding about origin of ergonomic problems present in working areas, (b) identifies the main unsafe and unhealthy areas and work system components, (c) supports the decision-making about improvement projects focused on risk elimination, (d) the workers´ fear of being dismissed by employers if they report symptoms of illness was diminished because the survey was anonymous. However, the workers' voice (complains) and the employers´ opinion in many cases were contradictory. Thus, it is necessary for new studies to implement strategies to balance the differences in opinion.

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