Evaluation of the Impact of Engineering Ergonomic Interventions on Musculoskeletal Hazards and Psychosocial Factors Among Packaging Workers in a Food Factory

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Abstract

Improper work-system designs and physical demands lead to awkward postures in packaging workers in food factories, particularly with tasks that require a high instance of repetitive motions (e.g., assembly), which causes musculoskeletal disorders and affects psychosocial factors in the workplace. This study aimed to determine the effect of ergonomic engineering interventions on musculoskeletal risks and psychosocial factors among packaging workers in a food factory in Saudi Arabia. Nordic Musculoskeletal Questionnaire and the Job Content Questionnaire (JCQ) were used to examine musculoskeletal risks and psychosocial aspects, respectively among 52 male workers which were divided into intervention group control group. Two evaluation periods were used after implemented the interventions (3 months and 6 months post-intervention). The results showed that the engineering ergonomic interventions significantly decreased the musculoskeletal risks at neck, shoulders, upper back and lower back of workers in both evaluation periods at 3 months and 6 months post-intervention. The intervention improved only three aspects in JCQ: decision latitude, physical job demand and psychological job demands before and post-intervention.

Keywords: Ergonomics Interventions, Musculoskeletal Symptoms, Psychosocial Aspects.

1. INTRODUCTION

In terms of safety and health, controlling ergonomic hazards at a workplace is one the main responsibilities related to protecting workers that organizations have. Improper workplace design can lead to many ergonomic hazards such as work-related musculoskeletal disorders (WMSDs) and fatigue. This, in turn, can lead to low productivity, injuries and lost work days [1]. Indeed, organizations can face different, significant problems, such as low productivity, increased medical and insurance costs, and increased human errors, due to WMSDs [2]. Poor workplace design not only affects individuals but also negatively impacts the organization and society as a whole (i.e., economic and psychosocial effects) [3]. It has been demonstrated that a proper design of workstations in terms of ergonomic features (e.g., anthropometric data and adjustable chairs) leads to a significant reduction in musculoskeletal hazards and improves job satisfaction [4,5]. In various sectors, such as industrial and services industries (e.g., healthcare), awkward postures and repetitive activities are two significant factors that lead to musculoskeletal disorders (MSDs) [6,7]. Poor workstation design in the workplace leads to awkward postures such as bending the back, over-bending the neck forward and torso twisting while performing a task with highly repetitive motions (i.e., assembly tasks and inspections), which leads to a significant impact on the worker’s back, arms, neck and legs and causes MSD symptoms to appear and poor productivity to occur [8,9]. Improper workstation design in the workplace forces an individual to take awkward postures such as back bending, twisting, reaching the hands too far forward and neck bending; these types of activities, particularly in highly repetitive tasks (i.e., assembly, packaging and inspection), lead to MSDs. The effects of physical demand and awkward postures on MSDs have been investigated widely [11]. The ergonomic hazards, such as repetitive activities, heavy manual tasks and awkward postures, are common in industry sectors such as electrical manufacturing, automobile manufacturing and the food industry (i.e., packaging process, inspection and assembly processes) [12].

In Saudi Arabia, the ergonomics issue has received too little investigation [13]. Furthermore, many tasks in factories depend on manual activity rather than automated systems, especially in the packaging process, assembly tasks and inspection tasks. In terms of ergonomic control measures, engineering controls, such as changes in the design of workstations, are significantly effective techniques in reducing MSDs compared to other control measures such as changing work methods (e.g., using ergonomic mechanical aids; [14,15]. Also, it has been proven that ergonomic interventions are useful not only for reducing MSDs but also for improving the psychological perception of the workers toward their task [3,16]. Applying ergonomics rules and guidelines in a workplace lead to significant positive impact workplace design, machines and tools as well as workers' health and safety [15,17].

Numerous studies have been implemented to evaluate the impact of ergonomic interventions on MSDs and performance [8,18]. However, most of these studies have been carried out concerning the impact of personal behavior, such as exercise, education treatment and training, on MSDs rather than the impact of engineering controls such as the redesign of the workplace and workstation [3,18]. Silverstein and Clark [18] stated that the implementation of ergonomic engineering interventions, in terms of reducing ergonomic hazards in the workplace, was more difficult than administrative ergonomic interventions such as training programs and exercises. It has been mentioned that ergonomic tools and methods are the most suitable techniques a workplace can apply to control such hazards (e.g., musculoskeletal problems), particularly ergonomic engineering controls such as redesigning the system and workstations [8]. The ergonomic hazards due to poor workstation design can lead to unacceptable levels of productivity due to increasing numbers of absences among workers [10,19]. Ergonomic interventions refer to changing and improving working conditions in order to reduce and avoid ergonomic hazards such as heavy physical loads, awkward postures and poor perceptions toward these types of hazards in the workplace. Applying ergonomic interventions helps companies to reduce costs (e.g., injuries and medical costs) significantly and improve productivity [15,20]. However, these interventions can be divided into administrative interventions (i.e., educational interventions), such as training, posters and workshops [3], and engineering interventions such as redesigning a workplace and workstations to reduce MSDs [21]. In addition, many authors have demonstrated that the ergonomic interventions (i.e., ergonomic training programs and posters) improve psychosocial factors in the workplace [18,22]. A study by May et al. [4] mentioned that providing workstations with ergonomic principles, such as workbenches with adjustable heights and ergonomic chairs, contributes significantly in improving workers' perceptions toward their work environment and job satisfaction. They stated that appropriate ergonomic workstation design and characteristics positively influence the workers' workstation satisfaction, which improves the workers' overall satisfaction toward a job.

Considering the appropriate workstation-design dimensions as an ergonomics intervention when setting up the assembly production line and other factors such as level lighting and container of parts helps solve many problems of assembly operations [23]. Implementation of proper ergonomic guidelines in workstation design leads to a balance between task workload and individual physical and mental capabilities [1]. Many ergonomics researchers have recommended adjustable workbenches and chairs in the workplace for seated tasks since these features significantly reduce musculoskeletal suffering and increase individual comfort and satisfaction [24]. Furthermore, Shikdar and Al-Hadhrami [15] concluded that ergonomic interventions, such as redesigning workstations and workplaces, significantly reduced MSDs among different working groups and improved workers' performance.

Applying ergonomic rules in workplace design, such as designing workstations with appropriate user-population dimensions, and provisions in ergonomic mechanical aids, such as conveyors and handcarts, would not only reduce ergonomic hazards (e.g., MSDs) and improve performance but also improve cycle time and reduce fatigue, thus leading to high individual productivity, particularly in repetitive tasks (e.g., assembly, inspection and packaging tasks) [15,25]. Nevertheless, most equipment and many workstations in industries like the Saudi food sector were imported from abroad [26]. Due to this issue, there is a lack of fit between the workers' body types and the design of the workstations and equipment in many workplaces, since there are variations in body types between countries. Therefore, this lack of fit leads to ergonomic problems and injuries among workers in a number of jobs such as assembly and inspection tasks. In addition, in developing countries, MSDs are considered a main cause of work-related injuries [27]. Furthermore, these tasks (e.g., packaging and inspection tasks) in Saudi Arabia depend on manual activities, meaning workers need to perform highly repetitive hand motions, use poor working postures and experience overexertion. Consequently, the exposure to ergonomic hazards, such as MSDs and psychosocial factors, is very high. Indeed, the number of ergonomics research studies and applications in certain industries, particularly in developing countries, is still too limited [15]. As a result, ergonomic risks caused by the poor design of machines, tools and workstations in the industrial workplace are common. The neglect of ergonomic guidelines and rules in design of the workplace can increase the risks of individual exposure to ergonomic hazards such as musculoskeletal problems, high physical loads and mental stress and fatigue, which lead to unacceptable performance and low workplace satisfaction [5,28]. For instance, the proper dimensions of a workbench or workstation cannot be applied without knowing the anthropometric data for the population considered [8]. Therefore, it seems that applying ergonomic interventions, ergonomic engineering interventions in particular, would lead to significant reduction of musculoskeletal hazards and improved job satisfaction.

The aim of the current study was to implement ergonomic engineering interventions (i.e., redesigned workstations) in workstations of spice-packaging lines in a food factory in Saudi Arabia; the objectives of the interventions are to examine the impact of ergonomic applications in reducing musculoskeletal symptoms and psychosocial factors among packaging workers.

2. METHODS

2.1 Design

The present study is interventional research, and it was conducted for 8 months (April 2014 to November 2014). The packaging task unit in a food factory includes three main sub-tasks: assembly items, inspection and package spices units. This study aims to examine the effect of ergonomic interventions (e.g., ergonomic engineering control measure: redesigned workstations) on MSDs and psychosocial factors among workers. The study's participants were all male and were employed in a food factory in Saudi Arabia. The work shift was scheduled from Sunday to Thursday and went from 7:30 a.m. to 4:30 p.m.; the Saturday shift went from 8:00 a.m. to 1:00 p.m. The factory management gave workers two break periods and one hour for lunch during the shift. In the current study, personal information for the participants was collected and included anthropometric data, age, heart rate (HR), level of education and number of years employed in the food factory.

2.2 Packaging Tasks

As mentioned previously, the present study evaluates the impact of redesigned workstations on MSDs and psychosocial factors among spice-packaging task workers in food factors in Saudi Arabia. The spice-packaging task unit includes three main sub-tasks, which are assembly task, inspection task and packing task. However, the management applied a job rotation among its production and packaging lines, so the workers were selected randomly from packaging groups and production groups.

Each packaging line includes three groups of participants; the first group involves six workers: four workers receive the spice-bag units from the production lines and each worker needs to assemble four units into one small box then pass the boxes to two workers who put the appropriate stickers on the boxes. The second group of workers involves two workers who perform the inspection process such as checking the number of spice-bag units in each box and sticker type; then they need to pass the small box through the Heat Shrink Tunnel (HST) machine in order to pack the four spice units into one plastic bag. The third group involves five workers: two of them put each of 3 the six plastic bags in one carton box and then feed this carton to a Taping Machine (TM). The other two workers are required to sort each type of spice carton box together. Finally, the last worker needs to lift the boxes and place them on a handcart to transport the boxes to the storage area, as illustrated in Figure 1. All similar processes apply for the other packaging lines.

2.3 Participants

A total of 52 males participated in this study. All participants were full-time employees in the food factory. These participants were distributed among four packaging lines with 13 participants for each line (see Figure. 1). The participants were divided into two groups: The intervention group contained 26 workers and the control group contained 26 workers; all were selected randomly. Each worker provided informed consent before the study began and all participating workers were paid.

The participants' characteristics (i.e., age, body mass index (BMI), weight, height and HR), anthropometric data and heart rate were observed at the beginning of the study (see Table 1) along with perceived job demands. Additionally, information details of workers, such as marital status, level of education and number of working years, were observed in this task, as illustrated in Table 2. The study checked (i.e., medical reports) for whether participants had experienced any musculoskeletal problems, back or shoulder pain and arm or neck discomfort in last 12 months.

2.4 Ergonomic Intervention and Workstation Design

The current study aims to improve the workplace design, particularly the workstation design from an ergonomic perspective, and thus, ergonomic intervention was applied. This intervention was developed in order to examine the effect of engineering ergonomics intervention on MSD symptoms and psychosocial factors among packaging workers in the food factory. The original workstations used in the spice-packaging line are similar in dimensions and features in all four lines in the factory.

However, each spice-packaging line includes five workstations, as illustrated in Figure 1, and the original dimensions of the first workstation were 2500 mm x 1100 mm x 850 mm, as shown in Figure 2 (a), whereas Workstations 2, 3, 4 and 5 had similar dimensions (1250 mm x 1100 mm x 850 mm; see Figure. 2 (b)).

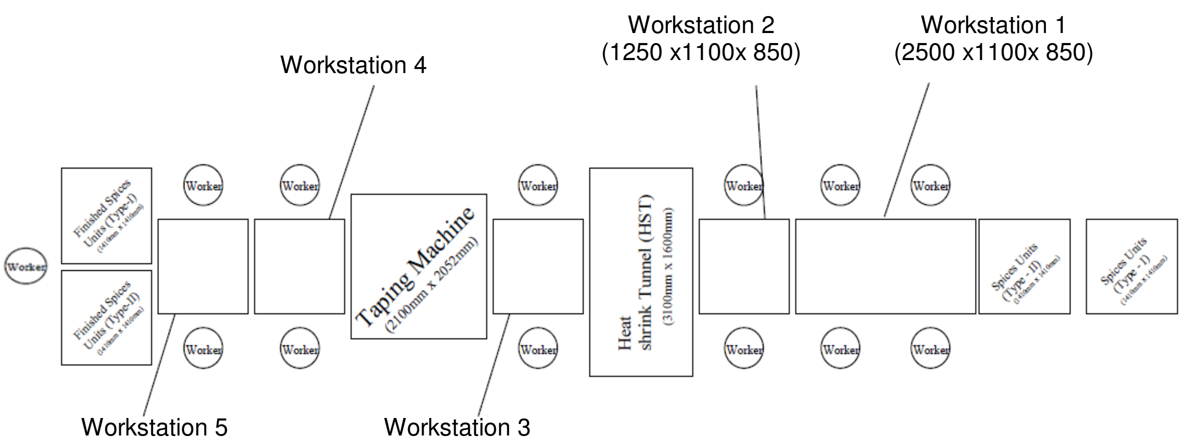

FIGURE 1: Top view of the original workstations design and layout of one packaging line; includes workers' distribution, the five workstations' dimensions and the machines. (Unit: mm).

There were four workers in the first workstation: two workers sitting next to each other with the other two across. In contrast, the other workstations each had only two workers who sat face to face. These workstation dimensions led to raised shoulders among the worker and led to shoulder angles with greater than 45° flexion and abduction greater than 35° while sitting and performing the packaging tasks, since the workstation height was too high for a majority of the workers (i.e., assembly task, inspection task and packing task). So, these types of postures were awkward and considered significant factors that led to MSDs [25,29]. According to previous research studies and OSHA rules, these angles in sitting postures have been considered critical issues in musculoskeletal symptoms [21]. In addition, the workstations had a sharp edge that affected the forearms of workers performing the tasks, leading to forearm stress and effects on blood circulation through the forearm and wrist [29]. Furthermore, the chairs used in packaging tasks were not appropriate from an ergonomic perspective; the chairs did not fit the anthropometric data of the workers. The original chair height was adjustable 330 x 460 mm. The chairs had strong padding but did not include a back support, which negatively impacted workers' backs.

In the workstation-surface design guidelines, the depth and width of workstation surfaces should accommodate the normal and maximum work areas [25]. The work surface should accommodate all items and objects used to perform a task, as a narrow work surface can increase hand motions, which raises stress and time consumption [8]. The original workstation depth (1100 mm; see Figure 2 (a) and (b)) was inadequate for the workers' grip-reach distance since, as mentioned previously, each worker sat across from another, which led to small workstation depth, which, in turn, led to mixing the units of spices between the two workers. In addition, the first workstation width (2500 mm; see Figure 2 (a)) and the other workstations' width (1250 mm; see Figure 2 (b)) were narrow and were not appropriate for the workers' anthropometric data. One important guideline in the workplace as an ergonomic feature is to provide a suitable footrest for shorter workers to reduce leg fatigue, particularly in stationary tasks such as assembly and inspection [1,30]. The worker at the end of workstation conducted highly physical repetitive movements because he needed to lift the spice boxes around four to six times per minute from the 5th workstation and put them in the movable handcart.

Variables	Total (n=52)	Intervention Group (n=26)	Control Group (n=26)	P-value
Age (year)	35.4±3.5	34.3±3.1	36.2±4.8	0.135
BMI	24.7±6.3	25.6±9.7	23.8±5.6	0.121
Height	173.5±5.6	174.4±6.4	172.0±8.1	0.112
Weight	82.9±9.3	84.2±8.1	81.7±10.3	0.246
HR-rest (beats/min) (Mean ± SD)	80.8±10.8	81.3±12.2	78.9±9.6	0.134
Employment duration in packaging tasks in year (Mean ± SD)	5.9±2.3	6.7±2.7	5.1±3.4	0.197
Marital status n (%)				
-Single	11 (21.2)	4 (15.4)	7 (26.9)	0.416
-Married	41 (78.8)	22 (84.6)	19 (73.1)	
Level of education n (%)				
-High school	41 (78.8)	21 (80.8)	20 (76.9)	
-Diploma	8 (15.4)	3 (11.5)	5 (19.2)	0.208
-BSc	3 (5.8)	2 (7.7)	1 (3.8)	

TABLE 1: All participants' characteristics for age, body mass index (BMI), marital status, employment duration in packaging tasks and levels of education and heart rate (HR).

According to previous information (see Table 2) and guidelines for workstation designs, the first workstation was redesigned with dimensions 2800 mm x 1450 mm x 750–1100 mm, as illustrated in Figure 3 and Figure 4 (a); in contrast, the other workstations had similar dimensions to one another: 1400 mm x 1450 mm x 750–1100 mm, as shown in Figure 3 and Figure 4 (b). The first redesigned workstation was increased in width by 300 mm in order for two workers seated beside each other to have enough working space; this size was used in order to accommodate the 5th percentile of forward grip reach of the sample size.

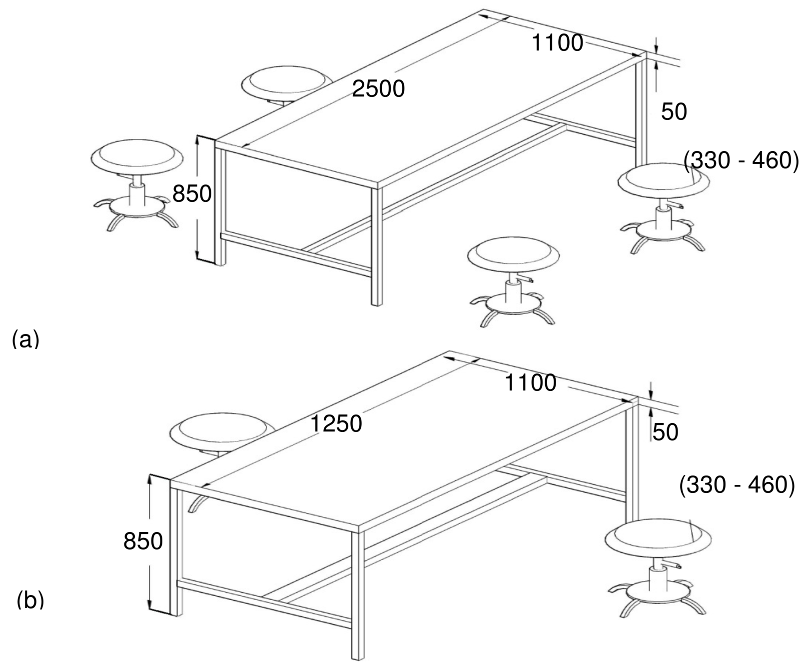

FIGURE 2: (a) The original Workstation 1 dimensions (2500 x1100x 850) and (b) the original dimensions of Workstations 2, 3, 4 and 5 (1250 x1100x 850); the worker chairs were similar among all workstations with adjustable height (330 x 460; unit: mm).

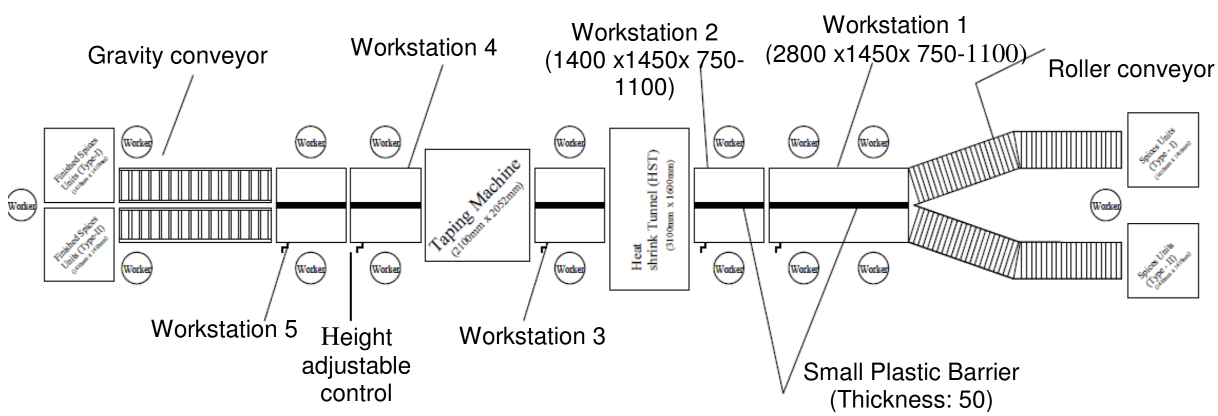

FIGURE 3: Top view of the redesigned workstations and layout of one packaging line; includes workers' distribution, the five workstations' dimensions, newly added conveyors and the machines (Unit: mm).

The depth of the table was increased by 350 mm to fit the 5th percentile of elbow-to-fit length for the sample size and multiplied by two since, as stated previously, there were two workers seated side by side across from the other workers (700 * 2 = 1400 mm); also, a strong plastic barrier (thickness = 50 mm and height = 50 mm; see Figure 3) was built in the middle of the workstation along the length of the each workstation, as illustrated in Figure 3, in order to avoid any overlap between the type of spice boxes between the two workers as a guideline to make the assembly process more comfortable and easy for each worker and reduce the assembly time [1]. According the anthropometric data that were observed (see Table 2), the height of all workstations was adjusted from 750 mm to 1100 mm to accommodate the majority of workers' sitting heights and in order to prevent awkward postures (i.e., shoulder flexion and abduction). The redesigns of Workstations 2, 3, 4 and 5 were similar to one another, and the height and depth of these workstations were similar to the first workstation, except the length was 1400 mm, since all these workstations involved two workers seated in front together (see Figure 4 (b)).

Parameters	Total (n=52)	Intervention Group (n=26)	Control Group (n=26)	P-value
Anthropometric data (cm) (5th, 50th, 95th)				
-Sitting height	87.9±7.6 (71.4, 88.8 , 94.1)	86.4±6.9 (72.3, 84.9 , 94.1)	87.3±9.1 (70.8, 83.5 , 96.4)	0.094
-Sitting elbow height	25.1±6.8 (13.4, 25 , 37.3)	25.2±7.7 (11.7, 25.5 , 38.2)	24.9±5.8 (14.3, 25.4 , 35.8)	0.142
-Elbow to fit length	44.1±3.3 (35.4, 42.3, 48.8)	43.7±3.4 (36.1, 41.6 , 48.4)	44.3±3.6 (35.8, 44 , 49.1)	0.104
-Forward grip reach	73.3±3.0 (68.1, 72.6, 81.4)	74.0±3.1 (68.6, 73.4 , 80.3)	72.6±2.8 (67.4, 71.8 , 82.5)	0.137
-Popliteal height	51.9±5.2 (41.8, 50.6 , 58.1)	50.3±4.2 (42.2, 50.1 , 57.8)	52.5±6.1 (41.0, 49.2 , 59.3)	0.128
-Thigh clearance height	14.5±3.0 (6.7, 12.4 , 17.1)	15.1±3.6 (7.4, 13.3 , 17.2)	13.8±2.4 (5.6, 11.1 , 16.8)	0.151

TABLE 2: Some anthropometric parameters for all participants', intervention group and control group Mean ± SD.

2.5 Output Measures and Data Collection

The current research study used two methods in order to evaluate the effect of ergonomic engineering interventions in workstations of packaging units in a food factory. First, the Nordic Musculoskeletal Questionnaire (NMQ) was used to assess the impact of new workstation designs on musculoskeletal prevalence levels among participants' body regions. This questionnaire has been used widely to evaluate MSDs among individuals in different working postures and various tasks in different sectors such as healthcare, industrial and office work [3,27,32].

Secondly, the Job Content Questionnaire (JCQ), English version, was used to assess the impact of newly proposed, redesigned workstations on psychosocial factors. According to Choobineh et al. [3] JCQ was used often in numerous researches in various countries to examine the effect of job workload on MSDs and psychosocial aspects. JCQ has been used commonly in different, numerous studies to evaluate the impact of work conditions and workload on physical demand and psychological load [33,34]. There were five main items used in the JCQ, including the following: decision latitude (9 sub-items), which includes skill discretion and decision authority, physical job demands (5 sub-items), psychological job demands (9 sub-items), occupational physical hazards (8 sub-items) and social support (8 sub-items), which includes supervisor support and coworker support items [3,34]. These items were evaluated using a 4-point scale: 1 (strongly agree), 2 (agree), 3 (disagree) and 4 (strongly disagree).

The NMQ and JCQ were collected before and after implementation of the redesigned workstations. The questionnaires were completed before ergonomic interventions were applied for the workstations; the data collected from these questionnaires were observed after 3 months of intervention and 6 months post-intervention of the study. The data collected from the 52 participants were completed in 10 working days for each of the three periods (i.e., before intervention, three months after intervention and six months after intervention) of data observations. NMQ and JCQ were completed by workers during each of the data observation periods.

2.6 Data Analysis

Statistical analysis SPSS (Version 22) software was used to carry to the data analysis. The Wilcoxon (signed-rank) test was used to find the differences between the intervention group and control group at a baseline level (i.e., before implemented the intervention) in terms of demographics, participants' characteristics for age, body mass index, marital status, employment duration in packaging tasks, level of education, HR and anthropometric data. Furthermore, the Wilcoxon (signed-rank) test was used to determine the difference in musculoskeletal symptoms scores and JCQ items scores between the two groups before intervention, 3-month post-intervention evaluation period and the 6-month post-intervention evaluation period. A Paired t-test was used to determine the difference between the musculoskeletal symptoms scores and JCQ scores in each group. A 95% confidence level (i.e. $\alpha = 0.05$) was used in the present study.

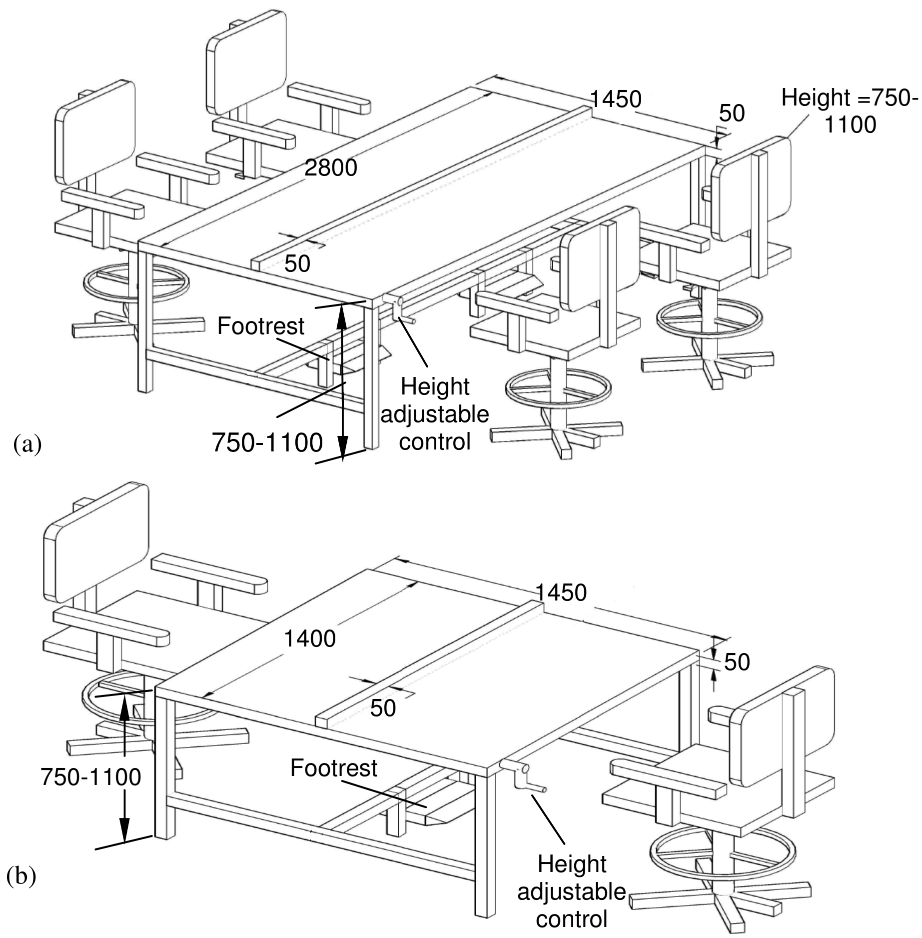

FIGURE 4: (a) Redesigned Workstation 1 dimensions (2800 x 1450 x 750–1100; unit: mm) and (b) the original dimensions of Workstations 2, 3, 4 and 5 (1400 x 1450 x 750–1100); the worker chairs were similar among all workstations with adjustable height (530 x 680; unit: mm).

3. RESULTS

The objective of this study was to investigate the influence of ergonomics engineering control of the spices-packaging unit of a food factory in Saudi on workers' musculoskeletal prevalence and psychosocial issues. According to the analysis, there were no significance differences between intervention group (n=26) and control group (n=26) in participants' characteristics, as shown in Table 1 (e.g., age, BMI, weight, height HR). Also, the study found that the differences between groups in employment duration, marital status and level of education were not significant. As seen in Table 2, there were no significant differences between the means of both groups in the anthropometric data that were collected.

3.1 Nordic Musculoskeletal Questionnaire: Intervention Group Vs. Control Group

The Wilcoxon test analysis found significant differences between intervention group and control group at neck, shoulders and lower back regions in 3 months post-intervention as well as 6 months post-intervention ($p < 0.05$) (see Table 3). In contrast, there were no significant differences ($p > 0.05$) between both groups before-intervention period; except differences found between the groups in the foot region at that period, as depicted in Table 3. The intervention group had significant lower wrist/lower arms risk rate than the control group only at 6 months post-intervention period ($p = 0.022$).

Table 3 shows a significant difference between two groups before intervention regarding feet/ankles (p = 0.038). Wilcoxon test indicated there were no significant differences between both groups in all body parts before intervention except feet/ankles, as illustrated in Table 3.In terms of evaluation periods, the Paired t-test found that the musculoskeletal symptoms in the intervention group were significantly decreased after implementing the intervention. The results of the intervention group showed that the MSDs problems of neck, shoulders, wrist, upper back and lower back in 3-months post-intervention period were significantly lower than the problems of before-intervention period ($p = 0.004$), ($p = 0.024$), ($p = 0.029$), ($p = 0.019$) and ($p = 0.001$), respectively (see Figure 5).

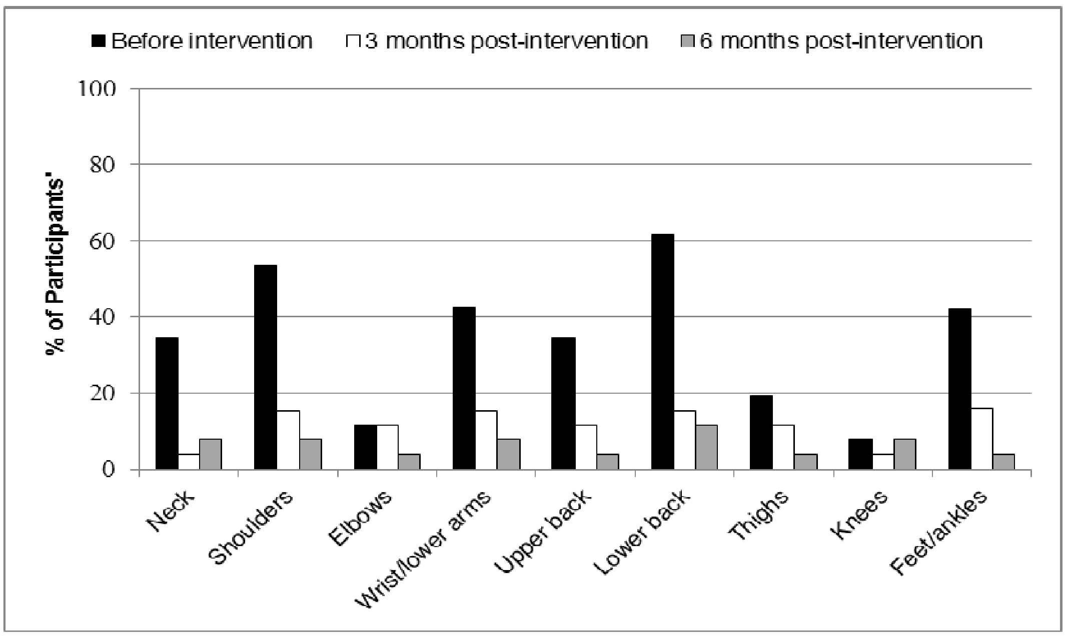

FIGURE 5: Percentage of workers in intervention group according to musculoskeletal risks over the three evaluation periods (before intervention, 3 months post-intervention and 6 months post-intervention; n=26).

As expected, the prevalence of MSDs were reported to be significantly different between before intervention and the 6- months post-intervention period in the neck ($p = 0.007$), shoulders ($p = 0.008$), wrist ($p = 0.011$), upper back ($p = 0.006$) and lower back ($p = 0.003$), as demonstrated in Figure 5. By contrast, there were no significant differences between the two follow-up evaluation periods (3 and 6 months after intervention) in all body parts ($p > 0.05$).

In terms of control group, the Paired t-test concluded that there were no significant differences between musculoskeletal prevalence for spice-packaging workers in the before-intervention period versus 3 months after intervention period for all body parts (p > 0.05; see Figure 6). Similarly, the musculoskeletal problems between before-intervention period vs. 6 months after intervention were not significant ($p > 0.05$), as depicted in Figure 6.

3.2 Job Content Questionnaire (JCQ): Intervention Group Vs. Vontrol Group

The JCQ was used to assess the impact of workstation design (i.e., ergonomics engineering intervention) in spice-packaging lines in a food factory on psychosocial factors. The results of Wilcoxon (signed-rank) test showed that the significant differences between intervention group versus control group during the period of before intervention were observed only in decision latitude scores (p = 0.000) and physical job demand scores (p = 0.022; see Table 4). As illustrated in Table 4, the scores of physical job demands in the intervention group were significantly lower than the scores of the control group in both follow-up periods 3 and 6 months post-intervention (p = 0.012 and p = 0.007), respectively.

Moreover, in the intervention group, the psychological job-demand scores were significantly decreased compared with the scores of the control group in a period of 3 months post-intervention (p = 0.013) and period of 6 months post-intervention (p = 0.018). No differences related to occupational physical hazards and social support were found in the groups before intervention and after intervention periods (p > 0.05; see Table 4).

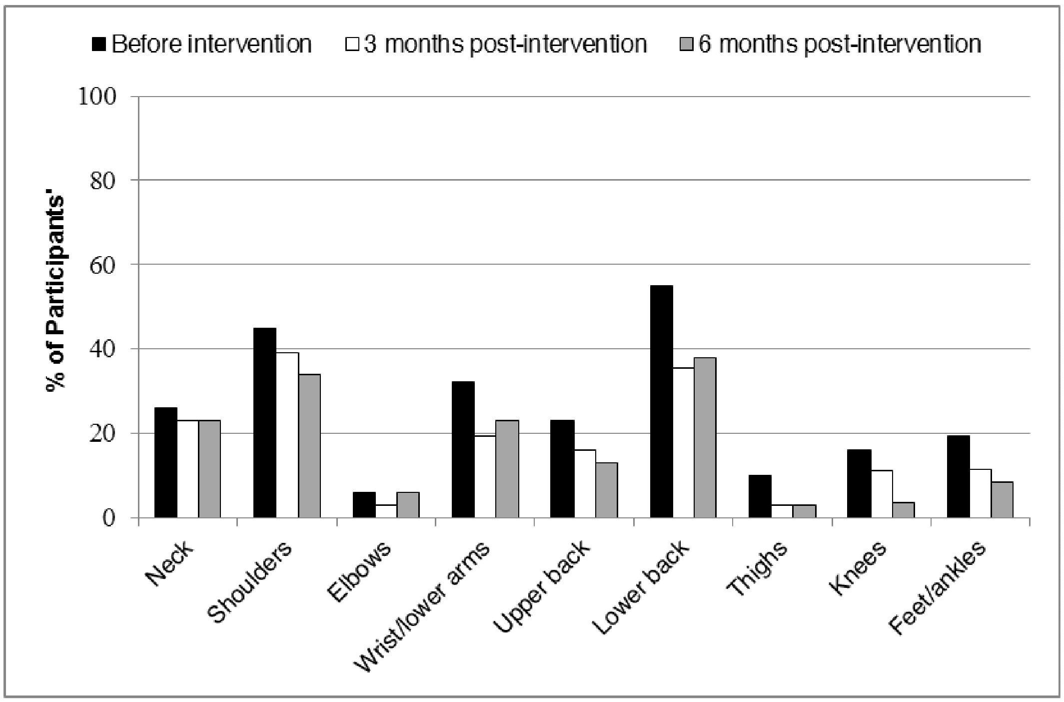

FIGURE 6: Percentage of workers in control group according to musculoskeletal risks over the three evaluation periods (before intervention, 3 months post-intervention and 6 months post-intervention; n=26).

In terms of intervention group and periods of evaluation, according to the Paired t-test the decision latitude scores significantly decreased after intervention in both follow-up periods compared with the before-intervention period; 3 months post-intervention versus before intervention (p = 0.000), and 6 months post-intervention versus before intervention (p = 0.000). Likewise, the scores were significantly lower in physical job demands and psychological job demands in both periods after intervention compared to the before-intervention period (p = 0.000), as shown in Table 4. The findings indicated that there were no significant differences between the before-intervention period versus 3 months post-intervention (p > 0.05) and the before-intervention period versus 6 months post-intervention (p > 0.05) in occupational physical hazards and social support items (see Table 4).

For control group, the Paired t-test found that there were no significant differences between scores before intervention and follow-up periods 3 months post-intervention as well as 6 months post-intervention (p > 0.05) in all JCQ items as illustrated in Table 4.

Body parts	Intervention Group (n=26) Yes(%)	No(%)	Control Group (n=26) Yes(%)	No(%)	P-value
-Neck					
Before intervention	9(34.6)	17(65.4)	7(26.9)	19(73.1)	0.142
Three months post-intervention	1(3.8)	25(96.2)	6(23.1)	20(76.9)	0.013*
Six months post-intervention	2(7.7)	24(92.3)	6(23.1)	20(76.9)	0.036*
-Shoulders					
Before intervention	14(53.8)	12(46.2)	12(46.2)	14(53.8)	0.151
Three months post-intervention	5(19.2)	21(80.8)	10(38.5)	16(61.5)	0.031*
Six months post-intervention	2(7.7)	24(92.3)	11(42.3)	15(57.7)	0.028*
-Elbows					
Before intervention	3(11.5)	23(88.5)	2(7.7)	24(92.3)	1.000
Three months post-intervention	3(11.5)	23(88.5)	1(3.8)	25(96.2)	1.000
Six months post-intervention	1(3.8)	25(96.2)	2(7.7)	24(92.3)	1.000
-Wrists/lower arms					
Before intervention	11(42.3)	15(57.7)	8(30.8)	18(69.2)	0.084
Three months post-intervention	4(15.4)	22(84.6)	5(19.2)	21(80.8)	1.000
Six months post-intervention	2(7.7)	24(92.3)	6(23.1)	20(76.9)	0.042*
-Upper back					
Before intervention	9(34.6)	17(65.4)	6(23.1)	20(76.9)	0.109
Three months post-intervention	3(11.5)	23(88.5)	4(15.4)	22(84.6)	1.000
Six months post-intervention	1(3.8)	25(96.2)	3(11.5)	23(88.5)	1.000
-Lower back					
Before intervention	16(61.5)	10(38.5)	14(53.8)	12(46.2)	0.079
Three months post-intervention	2(7.7)	24(92.3)	10(38.5)	16(61.5)	0.021*
Six months post-intervention	2(7.7)	24(92.3)	11(42.3)	15(57.7)	0.016*
-Thighs					
Before intervention	5(19.2)	21(80.8)	3(11.5)	23(88.5)	0.084
Three months post-intervention	3(11.5)	23(88.5)	1(3.8)	25(96.2)	0.243
Six months post-intervention	1(3.8)	25(96.2)	1(3.8)	25(96.2)	1.000
-Knees					
Before intervention	2(7.7)	24(92.3)	4(15.4)	22(84.6)	0.187
Three months post-intervention	1(3.8)	25(96.2)	3(11.5)	23(88.5)	0.172
Six months post-intervention	2(7.7)	24(92.3)	1(3.8)	25(96.2)	1.000
-Feet/ankles					
Before intervention	11(42.3)	15(57.7)	6(23.1)	20(76.9)	0.038*
Three months post-intervention	4(15.4)	22(84.6)	3(11.5)	23(88.5)	1.000
Six months post-intervention	1(3.8)	25(96.2)	2(7.7)	24(92.3)	1.000

TABLE 3: Risk rate of musculoskeletal symptoms in various body parts of all 52 male workers of four spices-packaging lines. *indicated the significant difference between intervention group and control group over the various evaluation periods.

4. DISCUSSION

Many studies have evaluated the impact of ergonomic intervention, such as ergonomic training programs, on reducing musculoskeletal problems between workers in different sectors, whereas research on the effect of engineering ergonomic interventions, such as designing workstations and workplace layout on musculoskeletal risks, is still rare [1,8]. In addition, the impact of ergonomic intervention psychosocial aspects among workers has received little attention [3]. This study was carried out to examine the effect of ergonomic intervention in particular workstation design on musculoskeletal symptoms and psychosocial variables between workers in spice-packaging lines at a food factory in Saudi Arabia. As mentioned, the current study implemented the ergonomics rules in workstation design of spice-packaging lines and other ergonomic features such as chair design and foot rest.

JCQ Scale Items	Intervention Group (n=26) Mean (± SD)	Control Group (n=26) Mean (± SD)	P-value
- Decision latitude			
Before intervention	68.615 (± 5.431)	63.374 (± 6.829)	0.000*
Three months post-intervention	63.847 (± 2.076)	63.293 (± 5.082)	0.429
Six months post-intervention	62.293 (± 3.187)	62.686 (± 6.281)	0.349
- Physical job demands			
Before intervention	11.708 (± 3.691)	14.375 (± 2.581)	0.022*
Three months post-intervention	9.364 (± 2.234)	13.067 (± 1.874)	0.012*
Six months post-intervention	8.831 (± 1.406)	13.215 (± 2.053)	0.007*
- Psychological job demands			
Before intervention	10.412 (± 3.641)	11.028 (± 2.856)	0.236
Three months post-intervention	7.954 (± 2.672)	10.736 (± 2.559)	0.013*
Six months post-intervention	7.317 (± 2.893)	10.427 (± 3.038)	0.018*
- Occupational physical hazards			
Before intervention	18.731 (± 3.068)	19.358 (± 2.504)	0.135
Three months post-intervention	17.597 (± 3.418)	18.186 (± 2.391)	0.194
Six months post-intervention	17.318 (± 4.422)	18.812 (± 3.116)	0.186
- Social support			
Before intervention	23.826 (± 2.516)	23.551 (± 2.448)	0.374
Three months post-intervention	23.258 (± 2.861)	23.113 (± 2.097)	0.691
Six months post-intervention	23.023 (± 3.028)	23.219 (± 2.115)	0.732

TABLE 4: Mean (± SD) of English version of the job content questionnaire of all 52 male workers of four spices-packaging lines (intervention and control groups)*indicated the significant difference between intervention group and control group over the various evaluation periods (p<0.05).

4.1 Nordic Musculoskeletal Questionnaire Vs. Intervention Group and Control Group

The results of this study showed that the ergonomic interventions applied were significantly contributed in reducing musculoskeletal loading among spice-packaging workers. The changes in workstations in the spice-packaging line with the appropriate workers' anthropometric data reduced the shoulder angles, abduction and musculoskeletal pains in different body parts. The workstations changed from fixed height (850 mm), which was not suitable for most workers, to adjustable height range (750–1100 mm) supported in reducing awkward postures in the neck and shoulders. That is, the introduction of workstation adjustability reduced the stress previously imposed on workers' muscles due to fixed workstation height. Accordingly, awkward postures among spice-packaging workers were greatly reduced. Research has shown that the impact of adjustable workstation height in muscles loading reduction is significant [8,24]. Thus, using adjustable workstations with ergonomically designed chairs should lead to a decline in shoulder symptoms among workers by reducing load on their trapezius muscles. The results of the current study consistent with the findings of previous authors who found that adjustable-height computer workstations significantly reduced poor shoulder and neck postures among semiconductor fabrication workers in a Taiwanese factory by reducing the demands on their trapezius muscles and neck muscles [8]. Furthermore, the musculoskeletal symptoms declined significantly after implementing the intervention in chair design and workstations. The percentage of neck, shoulder, wrist, upper back, lower back, and feet musculoskeletal symptoms decreased significantly among intervention groups after the intervention was applied in both evaluation periods of 3 and 6 months post-intervention. This may be because the new ergonomic features added to new chairs beside the new workstation dimensions facilitated the reduction in musculoskeletal pains among the workers in the mentioned regions. The current results are in agreement with the results of other research studies that found reductions in MSDs for different body parts such as the wrist, shoulder, low back, and neck due to the use of adjustable workstations and ergonomic chairs [15,24]. According to Robertson et al. [5] the chairs with ergonomics characteristics significantly impact musculoskeletal disorders, such as low back pain and arms in particular, in seated tasks and repetitive motions tasks. The current findings were consistent with the findings of previous research that approved the consideration of ergonomics in rules and guidelines in workstation design (e.g., appropriate dimensions for individuals) and their relation to decreasing musculoskeletal discomfort [4,15,24]. Redesigned workstations and ergonomic chairs may have contributed significantly to workers' perceptions of the reduction of pain in various body parts, so their subjective feelings were positively improved. The intervention group effect in the present study might be attributed to workers perception of redesigned workstation and ergonomic chairs values. Therefore, the workers in intervention group were declined static muscle loads and improve their postures. Importantly, the conveyors used in the current study facilitated the process transfer of spice boxes and eliminated the repetitive lifting of spice boxes; therefore, low back and arm problems, in particular, were reduced at 6 months post-intervention.

However, the results indicated that there were no significant differences in musculoskeletal load before ergonomic intervention between intervention group and control group. Oppositely, the participants in intervention group were observed to have a significantly lower musculoskeletal rate from the neck in the control group, shoulders and low back body parts at 3 and 6 months post-intervention periods. This suggests that the ergonomic interventions had an effective influence. The musculoskeletal prevalence of wrist problems among workers in intervention at 6 months post-intervention period was significantly lower than the rate in the control group since, the suitable height of workstation, hand support and the rubber materials provided to the sharp edges of all workstations, reduced the fatigue and load on lower arm and wrist. This may be the contribution of long term impact of appropriate height of workstation and ergonomic chairs features resulting in decreased posture stress and muscles loads on arms. The types of ergonomic interventions (i.e., workstation redesigned, new chairs, conveyors) that were used in the current study were contributed significantly with the long period of evaluation in body regions problems reduction. This results is compatible with previous study that declared the adjustable VDT workstation reduce awkward shoulder posture in 3 month after intervention among Taiwan operators [8]. It has been mentioned that the significant reduction in awkward shoulder posture at evaluation period of 3 month post-intervention are better than in the evaluation period of 1 month after intervention among Taiwan operators [8]. Furthermore, one researcher study has been demonstrated that the body parts disorders such upper pack, lower back and feet have been declined significantly at 6 month after intervention [3]. Also, the effect of ergonomics intervention at the workplace is clearly associated with reports of a long follow-up evaluation period (e.g., 6 months and one year post-intervention) after the intervention was implemented [18].

All the participants' characteristics, such as age, weight, height and anthropometric data, were controlled within the intervention group and control group, since, as mentioned previously, there were no significant differences between them and they had similar demographic characteristics. These factors can significantly impact musculoskeletal discomfort [4,8,28]. Moreover, the difference of musculoskeletal prevalence between the participants of the control group before and after intervention periods (i.e., 3 and 6 months post-intervention evaluation periods) was not significant. In the current study, the task demands and working circumstances were considered in order to control these important factors between intervention group and control group over the three evaluation periods. That means the intervention applied was effective and succeeded in reducing the musculoskeletal symptoms among the workers.

4.2 Job Content Questionnaire (JCQ): Intervention Group and Control Group

Generally, the JCQ scores were sensitive to ergonomic interventions (e.g., workstation design and chair design) that were implemented and other ergonomics features (e.g., conveyors and foot rest) that added to the spice-production lines. The results showed that the significant difference between intervention group and control group only appeared in the decision latitude factor before intervention. However, the significant difference between both groups occurred in physical job demands and psychological job demand factors after implementing the intervention and ergonomics features in follow-up evaluation periods 3 and 6 months post-intervention. The influence of the redesigned workstations and ergonomic chairs could be attributed to workers' feelings and perceptions of the benefits of the redesigned workspaces. As a result, worker satisfaction increased and poor posture stresses decreased. Moreover, the appropriate anthropometric measures between workstation and worker were found to contribute significantly to the decline in musculoskeletal disorders and emotional and physical stress due to unnatural postures. According to Shikdar and Al-Hadhrami [1] interventions based on redesigning assembly workstations significantly reduced static muscles loads and increased individual satisfaction and enhanced performance. In terms of intervention group and evaluation periods, the difference between workers' scores was observed with decision latitude, physical job demands and psychological job demands before intervention and after intervention periods. These results are similar to the findings of Driessen et al. [11] that the ergonomic intervention training program improved decision latitude among Dutch workers after 6 months of intervention implemented. Furthermore, according to Choobineh et al. [3] the ergonomics intervention training sessions significantly decreased the physical job demands among an Iranian oil refinery factory after 6 months of training was implemented.

These results indicated that the ergonomic intervention and other ergonomic features were effectively impactful. Since the change of workstation dimensions over the packaging lines, such as the two conveyors added at the beginning and end of lines, eliminated the poor postures and avoided repetitive lifting motions. Expectedly, the reduction of muscles demands and static load due to these mentioned features the satisfaction and productivity were increased. In addition, ergonomics chair features reduced the load on workers' body parts while performing the tasks. The plastic barrier that was added to the workstations, as mentioned previously, improved the fatigue on hand motions and the search for objects since overlap between objects of any two workers who sat face to face were avoided. As expected, all these ergonomic applications lead to reduced physical effort and job stress among the workers. Thus, job satisfaction increased, and workers saved time.

4.3 Strength and Limitations

It is important to mention the strength of this study: many studies in the ergonomic interventions field have focused on the influence of the implementation of ergonomic administrative control measures (e.g., training and posters) on musculoskeletal risks [18]. Moreover, studies of engineering ergonomic applications in industrial sectors on psychosocial issues are too rare, in particular those assessing tasks that need repetitive activities and physical loads [3,8,35] since most studies have concentrated on the impact of ergonomic training sessions on musculoskeletal problems in office work [16]. Therefore, the present study aimed to evaluate the effect of workstation design as an ergonomic engineering intervention for repetitive manual tasks (e.g., assembly, inspection and packing tasks) and applied general ergonomics rules (e.g., chair design and ergonomic mechanical aids) appropriate for reducing musculoskeletal symptoms and negative psychosocial aspects among spice-packaging line workers in a food factory. Future research should consider long-term evaluation (such as one year post-intervention) to assess the impact of ergonomic interventions. Additionally, the lack of ergonomic knowledge and skills among workers can negatively affect their musculoskeletal disorders; thus, future study should also focus on ergonomic training programs in addition to engineering controls as an ergonomic intervention in such tasks.

On the other hand, a limitation of this study was that it considered only two evaluation periods after the intervention and ergonomic rules were applied, which were 3 and 6months post-intervention. Therefore, the study recommended carrying out the evaluation of intervention effect after 12 months of intervention implementation, with the effect being that intervention can appear related to psychosocial aspects and workers satisfaction throughout a long time of period. Two subjective assessment tools were used in the current study due to limitation in measure tools, and these tools depend on the workers' judgment and self-evaluation, so the risk of bias between psychosocial factors is a potential issue. Due to the limitations of tools that can be used in this study, a future research study should use other measure tools such as objective direct measures (e.g., electromyography (EMG) and compressive force (CFs)), which could be useful to evaluate the ergonomics intervention on physical demands and posture loads separately from psychosocial affects.

5. CONCLUSIONS

The current study found that applying engineering ergonomic intervention, such as workstation design and chair design, with tasks that need repetitive motions and physical loads significantly contributed to avoiding and reducing the ergonomic hazards of musculoskeletal problems. It also concluded that the interventions improved the decision latitude, physical loads and psychological demands among workers as psychosocial factors. Therefore, the current study recommended that the management of industry sectors consider the importance of anthropometric measures for the workers in workstation design in particular, for tasks that need repetitive human body motions (e.g., assembly, inspection and packaging) in order to avoid any ergonomics risks. Additionally, management in industries needs to provide an adjustable workstation height instead of a fixed height and appropriate adjustable chair design, especially if the industry factory involves different numbers of heterogeneous individuals, in order to reduce the risk of musculoskeletal pains. They need also to consider the other ergonomics features such as mechanical aids (e.g., conveyors) and foot rests, which all improve the satisfaction and perception of workers towards their tasks.

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