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The Effectiveness of Ergonomic Intervention in Work-Related Postures and Upper Crossed Syndrome of Metal Industry Workers

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Abstract

Introduction: *Upper Crossed Syndrome (UCS) is a musculoskeletal disorder that mainly occurs due to awkward posture in a static position. Considering the impact of musculoskeletal disorders on individual and social life, and the limited studies carried out in metal industries, this study evaluated the effect of ergonomic interventions using engineering controls on work-related postures and skeletal abnormalities caused by UCS in one of the metal industries.* **Methods:** *In this interventional study, 132 welders, press, and warehouse workers who had symptoms related to UCS were included. There were 78 participants in the experimental group (43 welders and 35 press operators) and 54 warehouse workers in the control group. Sitting and standing workstations were evaluated using the RULA and REBA methods, respectively. Then, with the technical committee's decision, the necessary ergonomics interventions were carried out. After three months of applying the interventions, the postures were re-evaluated. The paired t-test method was used for intra-group evaluation, and the independent t-test was used to compare the experimental and control groups using SPSS*. **Result:** *This study showed that ergonomic interventions can significantly reduce the risk score of musculoskeletal disorders in different body segments in sitting and standing workstations. Examining the UCS of the experimental group with sitting activities after the intervention, the average angle of the forward head, round shoulder, and kyphosis was reduced by 3.89, 4.05, and 3.73 degrees, and with standing activities by 3.27, 2.70, and 3.10 degrees, respectively.* **Conclusion:** *The results of the study revealed that modifying the workstation has a significant role in reducing the UCS.*

Introduction

Work-Related Musculoskeletal Disorders (WMSDs) are among the significant problems that advanced and developing countries encounter [1]. Research shows that despite the increasing use of mechanized and automated processes, WMSDs remain the primary cause of lost time and elevated costs. Additionally, they are among the leading causes of work-related disabilities, occupational injuries, early retirement, and a key factor limiting movement and agility [2]. According to the WHO, approximately 1.71 billion people worldwide suffer from musculoskeletal disorders [3]. These conditions are the top causes of disability globally, with low back pain (LBP) being the leading cause of disability in 160 countries [3]. The annual global burden of work-related LBP is estimated at 22 million

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disability-adjusted life years [4]. Studies indicate that the prevalence of WMSDs among Iranian employees is notably high compared to other countries [5-6]. In a study involving 9813 workers, over 36% reported experiencing pain in their neck, shoulders, and back across various body segments [7]. Furthermore, out of 1439 workers studied in Iranian steel industries in 2012, 64.1% suffered from back pain, 47.8% from knee pain, and 44.8% from neck pain within a year [8]. Although musculoskeletal disorders can arise from multiple causes, numerous studies have highlighted that maintaining and repeatedly assuming awkward postures at work is the primary cause of WMSDs, and the main method of treatment involves correcting these positions [9-10].

A prevalent WMSD that occurs due to poor body posture, especially in sitting activities and static posture, is the upper crossed syndrome (UCS) [11-12]. This syndrome involves the musculoskeletal system, and as a result, the posterosuperior and anterior muscles of the neck (such as the pectoralis major and minor, levator scapulae, sternocleidomastoid muscles) are mainly shortened and the anterior deep muscles of the cervical spine and lower back of the shoulder girdle are inhibited, stretched and weakened [13]. These changes show themselves in forward head posture (FHP), round shoulder posture (RSP), and kyphosis [14]. The presence of these three abnormalities together can indicate UCS syndrome. This syndrome can cause abnormal kyphosis, biomechanical changes of the glenohumeral joint, and pain in the shoulder and chest areas [15]. If not treated, these types of disorders cause secondary adverse changes, which include extra load on the neck vertebrae, numerous reports of temporomandibular joint arthrosis (due to forward head), and mechanical pains in the head [16].

The metal industry is one of the most important economic sectors in any country's manufacturing industry. In this industry, due to heavy work, awkward posture, and repetitive movements during work, the prevalence of musculoskeletal disorders is high [17-18]. Therefore, it is necessary to take basic measures to prevent and treat these disorders. Redesigning the workstation is a basic control measure in ergonomics. Ideally, using engineering controls, such as the ergonomic design of the workplace, is the most effective intervention method to eliminate the work environment risk factors [19]. Considering the impact of musculoskeletal disorders on individual and social life on the one hand, and the limited studies that have been carried out in metal industries on the other hand, this study was conducted to evaluate the impact of ergonomic interventions using engineering controls on work-related postures and skeletal abnormalities caused by upper crossed syndrome in one of Iran's metal industries.

2. Method

2.1. Participants

The participants in this study were the workers of a factory producing metal structures. There were 150 male workers in the manufacturing sector working in welding, pressing, and warehouse units. According to the inclusion and exclusion criteria, 132 people could participate until the end of the study. The mean age and work experience were 33.07 (6.46) and 5.94 (2.32) years in the control group and 34.00 (6.24) and 5.66 (3.10) years in the experimental group.

In the present study, there were 78 participants in the experimental group, 43 welders and 35 press operators were examined, of which 40 people were working at standing stations and 38 people were sitting at stations. The control group was selected from among the warehouse workers (54 participants), 35 of whom had sitting activities while 19 were employed for standing activities.

All the workers were employed for the day shift (working from 8:00 a.m. to 4:00 p.m.) and had fixed positions at their workstations. They had a 15-minute break from 9:30 to 9:45 and a 30-minute break from 12:30 to 13:00.

2.2. Task Analysis

The following paragraphs provide the three main job descriptions in the Metal Industry.

2.2.1. Welder

In the industry under investigation, more than 90% of the welders (38 people) had a sitting workstation, and only 5 of them worked standing. Based on the map and experience, and after checking the cut parts, the welding operator connected the surfaces of the parts by welding. In general, 700 pieces were welded per day (about three pieces every 2 minutes). In unfavorable conditions, the welder had to bend down and perform welding to have more control over the piece. Sometimes, the welder had to carry the iron, too. According to the job analysis, the welder has an unfavorable neck and trunk posture in this situation.

2.2.2. Press Operator

The press operator worked standing for a long time (7 hours). When the production director announced the type and the number of the pieces to the press operator and if the mold was installed on the press machine, the operator started his work and he sometimes needed to cut the pieces as well. Improper postures for evaluation were selected while the operator was putting a piece under the press or removing a piece from under the press. Workers pressed approximately 5,000 pieces during their shift (12 pieces per minute).

2.2.3. Warehouse Worker

Since the warehouse workers had a wide range of duties, their activities were divided into two categories: sitting and standing activities, to be compared with the sitting and standing activities of the experimental group. Warehouse workers who had to do sitting activities packed and sorted the goods, and the ones who had standing activities monitored inventory and handled receipts, storage, loading, and unloading the goods.

2.3. Inclusion Criteria

Full-time workers with at least one year of experience in the industry were selected; their forward head angle exceeded 46 degrees; their rounded shoulders measured over 52 degrees; their kyphosis condition was greater than 42 degrees; the visual analog scale index gauged the intensity of their pain and should have been above 3 in the head, neck, shoulder, and thoracic spine areas [11, 20-21].

2.4. Exclusion Criteria

Those who had a history of doing professional sports, a history of fracture and surgery in the spine, shoulder girdle, and/or upper limbs, severe visual impairments that could not be corrected with glasses, and a lack of interest were excluded from the study.

2.5. Data Collection

This research utilized the RULA and REBA posture assessment checklists, a flexible ruler, and a video-camera. Their usage is detailed below.

2.5.1. RULA and REBA Methods

Rapid whole body assessment (REBA) and rapid upper limb assessment (RULA) are two widely used observational evaluation methods in ergonomics.

The REBA method focuses on whole body assessment, while the RULA emphasizes a rapid evaluation of the upper limbs [22-23]. In this study, acknowledging that the upper limb is more involved in sitting workstations and the entire body in standing positions, these two methods are employed to assess ergonomics. For both methods, risk indexes are defined based on the final scores obtained from each body segment, which inform the decision-making process regarding ergonomic measures.

2.5.2. Measuring Forward Head and Round Shoulder

The present study employed the lateral view photography method to measure the forward head angles and round shoulders [21]. For this purpose, the first three anatomical landmarks- the tragus, acromion process, and spinous process of the seventh cervical vertebra- were identified and marked. The subject was positioned standing and photographed from the side (with his left arm against the wall) using a digital camera at a distance of 265 cm. The angle of the connecting line between the tragus and the seventh cervical vertebra with a vertical line (forward head angle), as well as the angle between the acromion process and a vertical line (round shoulder angle), were measured using AutoCAD software

(Figure 1). The reliability of this method is favorable, and it has been utilized in numerous studies [21].

2.5.3. Hyperkyphosis Measurement Method

We used a flexible ruler to check the back arch angle. Different studies have shown that the flexible ruler has excellent sensitivity and validity, even compared to the X-ray machine [24-25]. To measure the angle of the back arch with a ruler, the T2 (second vertebra) spinous process was used as the arc's starting point, while the T12 spinous process served as the arc's end. To locate the T2 spinous process, the subject was asked to flex their neck, allowing for the identification of the most prominent spinous process, C6 (the sixth cervical vertebra), with T2 located three vertebrae below it. The T12 spinous process is at the same level as the lower edge of the 12th rib on both sides, so the edges of these ribs were simultaneously touched with the tips of the thumbs, and their path was traced upward and inward until the soft tissue of the body was no longer felt. By drawing a straight line connecting the tips of the two thumbs, the location of the T12 spinous process was estimated. After determining the intended points, the examinee was asked to stand naturally and comfortably with bare feet on the cardboard, where their feet were to be placed, look forward, and ensure their weight was evenly distributed on both feet [24]. The flexible ruler was then placed along the individual's back. Even pressure was applied along the ruler's length to ensure there was no gap between the ruler and the person's skin, allowing it to contour to the back arch. The ruler's side in contact with the selected points was marked (Figure 1). After that, without altering the shape of the flexible ruler, it was gently and slowly removed from the back with both hands and placed on a piece of white paper. The curvature of its convex part was drawn on the paper, and points T2 and T12 were marked. To calculate the back arch angle from the shape obtained from the flexible ruler, points T2 and T12 were connected with a straight line, and a line was drawn from the deepest part of the curve to this line. These two lines were referred to as L and H, respectively. After measuring lines L and H with a 30-cm ruler, their values were entered into the formula.

$$\varphi = 4\text{Arctg } 2H/L$$

and the back arch angle was calculated [26-27].

2.6. Data Collection

After the initial investigation, an increase in pain complaints and the emergence of symptoms related to musculoskeletal disorders led to the examination of 132 people by the end of the study.

All participants signed the written consent form after being informed about the study's objectives

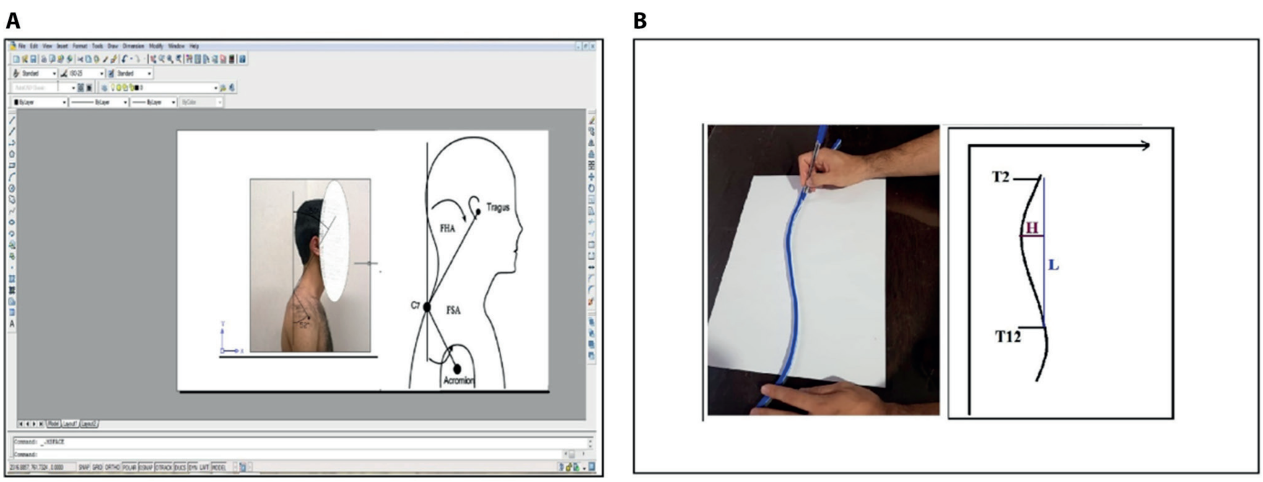

Figure 1. (A) Measurement of forward head and round shoulder; (B) representation of the thoracic curvatures on paper that showing the position of the spinous processes by lateral view photography method.

and evaluation procedures. The performers agreed to keep the workers' information confidential. If participants did not want to cooperate in any part of the study, they had the option to withdraw. This study was approved by the Ethics Committee of the Institute of Physical Education and Sports Sciences with the code IR.SSRC.REC.1402.219. Initially, the sitting and standing workstations in both experimental and control groups were evaluated by an ergonomic expert using the RULA and REBA methods, respectively.

In the RULA and REBA methods, according to the guidelines of both methods, an ergonomic expert selected and photographed the most frequent posture (the body position in which the person often works) after observing repetitive work cycles. In these assessments, both the right and left sides were measured, and the highest final score was considered. This study examined 38 sitting welding stations using the RULA method, along with 5 welding stations and 35 pressing stations using the REBA method.

Following that, based on the proposed protocols, a pathologist evaluated forward head angles, rounded shoulders, and kyphosis. Subsequently, with the decision of the factory's technical committee- comprising the technical manager, HSE and ergonomic experts, a production representative, pathology and corrective consultant, as well as the workers' representative- the necessary interventions were determined and then implemented in the experimental group with the cooperation of management.

It should be noted that, since the aim of this study was to investigate the effect of interventions on UCS, the focus was on interventions that could effectively reduce this syndrome. ISO 14738 and ergonomic documentation were used to implement these interventions [28].

In seated welding stations, based on ISO 14738, a plate with an angle of 30 degrees was added to the work table in an attempt to maintain the spine and shoulder girdle in a normal posture (Figure 2-A). Additionally, considering the height of the chairs, three footrests at heights of 10, 15, and 20 centimeters were provided to the workers on the condition that a 90-degree knee angle was maintained. Cold foam was also used for the seat material. Part of the welders' activity required carrying a piece of iron; therefore, a wheelbarrow was designed to move and transport iron (Figure 2-D).

The press workers' primary focus was designing a chair and a footrest. Some chairs for press workers were prepared according to Figure 2-C.

For five welders and nearly half of the press workers, a sit-stand chair was designed according to ISO 14738 to prevent the head and trunk from bending forward. The adjustable height of the sit-stand chair was calculated based on ISO 14738. This height was determined from the 95th and 5th percentiles of Iranian men, 89.4 and 74.1 cm. Consequently, the adjustable seat height was set to range from 74 to 90 cm.

$$F_{max} = 0.9\, h_6\, (P95) + X_1$$

$$F_{min} = 0.9\, h_6\, (P5) + X_1$$

h_6 = Crotch height: Vertical distance from the floor to the distal part of the inferior ramus of the pubic bone.

X_1= for shoes add 30 mm

After three months, the workstations were re-evaluated using postural risk assessment methods (RULA and REBA). Forward head angles, rounded shoulders, and kyphosis were also measured.

2.7. Statistical Analysis

Descriptive statistics were used to analyze qualitative variables, and indices of central tendency, such as the mean, along with dispersion indices, such as standard deviation, were applied for quantitative variables. The Shapiro-Wilk test yielded a p-value of 0.34, indicating that the normality assumption of the data is supported.

The paired t-test was utilized for intra-group evaluation (pretest-posttest), while the independent samples t-test was employed to assess and compare the experimental and control groups using SPSS (version 22) software.

3. Results

In the present study, conducted in a metal industry, the posture and upper crossed syndrome of

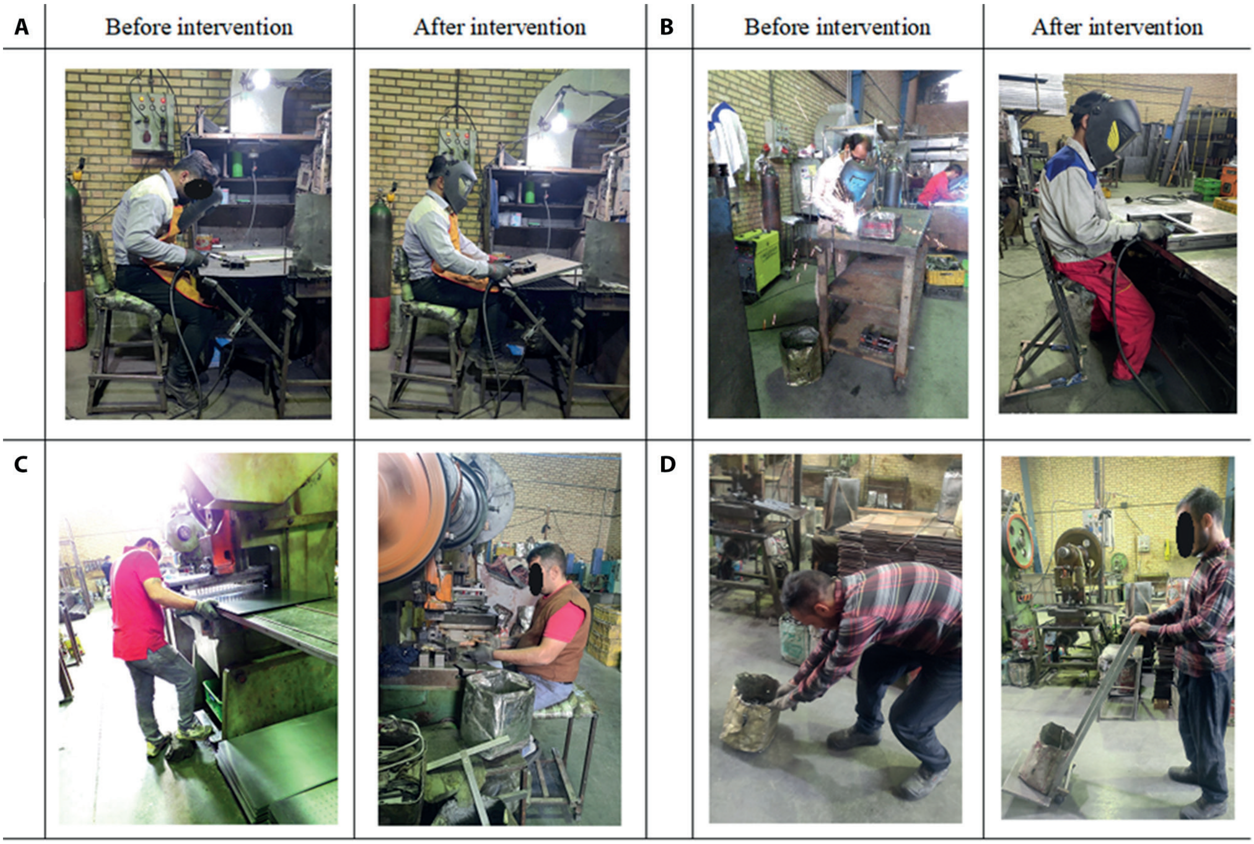

Figure 2. Some workstations before and after ergonomic intervention. A) Welding workstation, B) Welding workstation, C) Press workstation, D) Iron carrying posture.

132 workers who worked in sitting and standing workstations were evaluated before and after ergonomic interventions. The results are listed below by workstation.

3.1. Posture and Upper Crossed Syndrome Evaluation in a Sitting Workstation

3.1.1. Posture Evaluation in a Sitting Workstation

Assessment of posture in the sitting workstation was conducted using the RULA method. Table 1 presents the mean and standard deviation of the final scores obtained from the evaluation via RULA; the level of musculoskeletal disorder risk is also displayed separately for the control and experimental groups, both before and after the intervention. The difference in the experimental group's final score before and after the ergonomic intervention is clear; this change indicates a reduction of approximately 2 points in the final score from the evaluation methods. In contrast, the control group showed no difference in scores.

Table 1. Final score in the control and experimental groups in the sitting workstation (No. = 38).

	Sitting Group (RULA)	
Variables	Intervention Mean (SD)	Control Mean (SD)
Score c – Before (B)	4.74 (1.34)	3.14 (1.14)
Score c – After (A)	2.82 (0.80)	3.11 (1.10)
A-B	1.92 (0.94)	0.02 (0.01)

Comparing the scores of different areas in the experimental group, the mean final score for the body

Table 2. Forward head, kyphosis, and round shoulder angles in the control and experimental groups in sitting activities.

		Sitting group (Mean(SD) degree		
Variables (degree)	**Condition (time)**	**Experimental (n=38)**	**Control (n=35)**	**p-value**
Forward head	Before intervention	52.45 (3.108)	51.91 (4.097)	0.18
	After intervention	48.55 (3.696)	49.86 (4.097)	0.16
Round shoulder	Before intervention	55.82 (4.125)	54.37 (4.346)	0.15
	After intervention	51.76 (4.629)	54.20 (4.471)	0.02
Kyphosis	Before intervention	50.03 (4.044)	49.29 (4.315)	0.45
	Before intervention	46.29 (4.466)	49.23 (4.291)	0.006

segment changed. All body segments decreased (p<0.001) after the interventions.

3.1.2. Examining the Upper Crossed Syndrome in a Sitting Workstation

Table 2 compares the mean scores for forward head angles, kyphosis, and round shoulders in the control and experimental groups (sitting workstation). There is no significant difference between the angles in the control and experimental groups before the intervention; however, after the intervention, a difference appears between the two groups in the angles of kyphosis and round shoulders (p<0.05). In the experimental group, a difference exists between the mean scores for forward head angles, kyphosis, and round shoulders before and after the intervention.

3.2. Posture and Upper Crossed Syndrome Evaluation in a Standing Workstation

3.2.1. Posture Evaluation in a Standing Workstation

Table 3 presents the REBA scores of the experimental and control groups from standing workstations. Changes in the total REBA scores of the experimental group after the intervention period were significant, with *p* values of less than 0.05. On the other hand, the REBA scores of participants in the control group were consistently high before and after the intervention periods. The difference in the mean final score before and after correction in the experimental group shows a decrease of about 3 points in the final score of the evaluation methods. However, in the control group, no score difference was observed.

Table 3. Final score in the control and experimental groups in the sitting workstation (No. = 40).

	Group (REBA)	
Variables	**Intervention Mean (SD)**	**Control Mean (SD)**
Score c – Before (B)	7.82 (3.00)	6.84 (1.83)
Score c – After (A)	4.77 (2.16)	6.89 (1.76)
A-B	3.05 (1.11)	-0.05 (0.41)

The score postures of the upper arm, lower arm, wrist, neck, trunk, and leg before and after the intervention in the standing workstation. The mean REBA scores for different body segments before and after intervention in the standing workstation showed a highly significant difference ($P < 0.001$) by paired sample tests.

3.2.2. Examining the Upper Crossed Syndrome in a Standing Workstation

Table 4 compares mean scores descriptively for forward head angles, kyphosis, and round shoulder in the control and experimental groups in the standing workstation. The results show no significant difference between the angles in the control and experimental groups before the intervention. After ergonomic interventions, a difference was observed between the control and experimental groups in forward head and rounded shoulders (0.007>p<0.001).

Table 4. Forward head angles, kyphosis, and round shoulder in the control and experimental groups in standing activities.

Musculoskeletal disorders	Condition (time)	Standing group (Mean(SD) degree		p-value
		Experimental (n=40)	Control (n=19)	
Forward head	Before intervention	52.90 (4.01)	52.95 (5.08)	0.96
	After intervention	49.63 (4.08)	53.05 (5.14)	0.007
Round shoulder	Before intervention	56.15 (4.03)	56.58 (4.69)	0.26
	After intervention	53.45 (4.44)	56.53 (4.63)	0.001
Kyphosis	Before intervention	49.68 (4.27)	51.00 (4.07)	0.26
	Before intervention	46.58 (4.11)	51.05 (4.02)	0.001

Ergonomics interventions on the upper crossed syndrome from different angles of the experimental group for the standing workstation show a reduction of angles after the intervention.

4. Discussion

Major health problems in all societies include WMSDs, which are caused by various factors, including poor posture [29]. Awkward posture and workstation modifications have been identified as key goals of ergonomics. Therefore, the present study evaluated the effectiveness of ergonomic interventions utilizing an engineering control approach in workstations, as well as their effects on work-related posture and upper crossed syndrome.

4.1. The Effect of Interventions on Posture and Upper Crossed Syndrome in a Sitting Workstation

4.1.1. The Impact of Interventions on Posture in a Sitting Workstation

In this study, it was revealed that using an ergonomic intervention with an engineering control approach positively affects the working postures of the workforce. When assessed in the experimental group (sitting workstation), the mean final score of the RULA method decreased from 4.73 to 2.81 after three months of intervention, indicating that the level of musculoskeletal disorder risk shifted on average from medium risk (further investigation, change soon) to low risk (change may be needed).

Based on the redesign (Figure 2), a significant difference was observed between the scores of all the investigated segments, before and after the intervention. This indicates the positive effects of ergonomic interventions on work posture.

After applying the ergonomic interventions in different body segments, the most significant changes were in sitting activities related to the arm and wrist areas, with an average difference of 0.95. The decrease in the score of each segment can indicate the role of interventions in reducing the risk of musculoskeletal disorders. One reason interventions on the upper limb have a greater impact is the redesign of the desk and chair, where the access limit is closer and the worker's upper limb is more within normal reach while working.

Considering the importance of workstation modification and its role in reducing musculoskeletal disorders and increasing productivity, various studies have investigated the effect of ergonomic interventions according to the nature of the job. In many studies, observational methods such as RULA and REBA have been used to evaluate the effectiveness of ergonomic interventions [30-31]. However, the number of studies in the metal industries is limited. A 2021 study conducted in the metal casting industry showed that complaints from musculoskeletal disorders are highly prevalent and that ergonomic interventions can reduce both musculoskeletal complaints and fatigue [32]. In general, the findings of this study and other studies show that interventions, especially technical-engineering interventions, can be effective on workstation posture [33].

4.1.2. The Effect of Interventions on Upper Crossed Syndrome in the Sitting Workstation

The results of ergonomic interventions in this study demonstrated a positive effect on reducing upper cross syndrome in the evaluated workstations. In the experimental group's sitting workstation, after three months of intervention, three abnormalities—kyphosis, forward head, and rounded shoulders—decreased by 3.73, 3.89, and 4.05 degrees, respectively. Significant differences were found in rounded shoulder deformity and kyphosis before and after intervention ($p<0.001$), while no significant change occurred in the forward head angle.

Given that the workers were welders, job analysis revealed they had to bend their trunks and necks extensively, which placed pressure on their spines. Similar studies indicate high pressure on the spine and related muscles during welding. Therefore, we aimed to alleviate this tension by focusing on the design of the chair, work table, and footrest. The interventions appeared to positively impact all three angles over the three-month period, ultimately reducing upper cross syndrome issues by improving posture.

4.2. The Effect of Interventions on Posture and Upper Crossed Syndrome in a Standing Workstation

4.2.1. The Effect of Interventions on Posture in a Standing Workstation

Using the REBA method, the experiment's results on workers who engaged in standing activities revealed that the final score changed from 7.82 to 4.77. This indicates that the risk index has shifted from high risk (investigate and implement change) to medium risk (further investigate), requiring changes soon.

Based on the redesign of the standing workstation (Figure 2), a significant difference was observed between the scores of all areas before and after the intervention, indicating the positive effects of ergonomic interventions on work posture.

The most significant changes after applying the ergonomics intervention in standing workstations and different body segments were related to the trunk and arm areas, respectively, with average differences of 0.63 and 0.43.

It should be noted that since most of the workers in the standing workstation were press operators, according to the experts, most alterations focused on changing the standing workstation into a sitting or sitting-standing station. It seems that with the redesign of the workstation, which now supports the trunk area more than before and increases the safer reach limit, the scores have decreased, especially in the trunk and arm areas.

4.2.2. The Effect of Interventions on Upper Cross Syndrome in a Standing Workstation

In the standing activities of the experimental group, after the intervention, kyphosis, forward head, and round shoulder decreased by 3.10, 3.27, and 2.70 degrees, respectively. The difference between the two evaluations (before-after) was significant ($p<0.01$).

The press machine operator had to bend his neck and trunk while working, and there was no support for his lower body. However, due to the modification and redesign of the press operators' workstation, which includes the design of a standing-sitting chair or a high chair with a footrest, efforts were made to reduce the pressure on the trunk and neck. Additionally, footrests during long-term standing activities increase comfort by relieving pressure on the cardiovascular system. It seems that modifying workstations helps the posture of different body segments align more closely with a neutral position, thereby reducing the angles of abnormalities.

Most similar studies have focused on corrective exercises and their effect on upper crossed syndrome, the results of which indicate the positive effect of these interventions [34-35]. Limited studies have been conducted on the impact of ergonomic interventions on upper crossed syndrome, which aligns with the present study. However, their results show the improvement of abnormalities related to forward head, rounded shoulders, and kyphosis [12, 36]. Modifying the workstation, on one hand, results in the stretching of shortened muscles; on the other hand, it strengthens weak muscles. Future studies should investigate the effects of engineering, educational, and management ergonomic interventions in complementary and combined methods to reduce WMSDs.

5. Conclusion

The results of the present study showed that by applying interventions with an engineering approach that focused on modifying the workstations of welding and pressing operators by using measures like adjusting the height of tables and chairs and using footrests, employees' posture improved, especially in the upper limbs and trunk. Also, the findings of the statistical tests showed that the implementation of ergonomic interventions has an effective role in reducing the upper crossed syndrome.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Ethics Committee of SPORT SCIENCES RESEARCH INSTITUTE (SSRI. REC_2310_2490 and The date of acceptance is 22 - 11 - 2023)."

Informed Consent Statement: Informed consent was obtained from all subjects involved in this article.

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