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Postural Loading Assessment in Assembly Workers of an Iranian Telecommunication Manufacturing Company

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Background. *Changes in industries and work practices have coincided with work-related musculoskeletal disorders (MSDs). This study was conducted to determine the prevalence of MSDs and to assess postural loading in assembly workers of an Iranian telecommunication manufacturing company.* ***Methods.*** *Data were collected from 193 randomly selected workers in 4 units of the company. The Nordic musculoskeletal disorders questionnaire and the UBC ergonomic checklist were used as data collection tools. Loading on the upper body assessment (LUBA) was used to assess postural loading.* ***Results.*** *Lower back symptoms were the most prevalent problems among the workers (67.9%). LUBA showed that most assembly workers (94.3%) had experienced considerable and high postural loading (postural load index,* PLI > 5*). Regression analyses revealed that lighting, rotation, contact stress, repetition, gender and age were factors associated with symptoms.* ***Conclusion.*** *Work-related MSDs occurred at a high rate among workers. Postural loading requires consideration. Any ergonomic intervention should focus on eliminating ergonomic factors associated with symptoms.*

musculoskeletal disorders   postural loading   assembly workers   LUBA

1. INTRODUCTION

Changes in industries and work practices, especially in assembly line work, have coincided with a growing problem of work-related musculoskeletal disorders (MSDs). Musculoskeletal injuries and disorders are a serious concern for the work force [1]. MSDs are a leading cause of occupational injury and disability in the developed and industrially developing countries [2, 3, 4, 5]. The economic loss due to those disorders affects not only the individual but also the organization and the society as a whole [4]. At present, MSDs are an important problem ergonomists

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encounter in the workplace around the world [6]. In many countries, preventing work-related MSDs is a national priority [7]. MSDs may affect the upper limbs, back and lower limbs and can result in pain, discomfort or numbness [8]. Work-related MSDs are multifactorial and associate with some occupational risk factors including physical work-related factors such as force, posture, movement, vibration and local contact stress [9, 10, 11, 12], psychosocial stressors [13, 14, 15] and individual factors [16]. Extreme postures are considered one of the main risk factors for musculoskeletal injuries. A review of the scientific evidence for a relationship between physical work factors and MSDs found strong evidence of awkward posture as a risk factor for disorders of the neck, shoulders, back and wrists/hands [17].

Assembly work in the automotive, engineering and electrical industries is important in view of employment [18]. Landau, Rademacher, Meschke, et al. stated that the number of MSDs, especially spinal disease and repetitive strain injuries in the hand–arm–shoulder system has been increasing. This problem had to be focused on, not only because of the economic costs involved, but also because these diseases deteriorate the quality of life. A study of car assembly line workers reported a high prevalence of upper extremity problems [19].

In the communication industry, where electronic devices and equipment for communication purposes are manufactured and assembled, workers experience long hours of static work. In this industry, awkward posture and repetitive movements are very common [20]. Most job activities are characterized by seated posture with the worker's head and trunk bent forward and the shoulders flexed and abducted, or standing posture outstretched to reach for overhead components. The aim of the present study was to investigate the prevalence of musculoskeletal symptoms, assess postural loading and examine possible relationships between musculoskeletal symptoms and risk factors among assembly workers of an Iranian telecommunication manufacturing company, Shiraz, Iran.

2. MATERIALS AND METHODS

2.1. Study Subjects

This cross-sectional study was conducted at a telecommunication manufacturing company, which employed 500 male and female assembly workers. Two hundred and twenty randomly selected workers from all four units of the company, i.e., board assembly unit (BAU), rack assembly unit (RAU), telephone assembly unit (TEL) and cable assembly unit (CABLE), with at least one-year job tenure participated in this study. As TEL was a small unit, all workers in this unit (n = 9) were investigated. Workers with problems that affected the musculoskeletal system because of accidents, or congenital or background diseases were excluded from the study (27 workers).

2.2. Characteristics of Tasks and Units

At BAU, workers produced boards for telephone sets or communication equipment in seated static posture. Repeated hand movements, neck and trunk rotation, back and neck bent were very common (Figure 1). The mean (*SD*) general and local level of illumination in this unit was 260 (111) lx.

At RAU, metal frames or racks for communication equipment were produced. Then, boards prepared in BAU were assembled on the racks. This was done in both seated and standing postures. While assembling high racks, awkward postures of the shoulders and arms were considerable. The mean (*SD*) general and local level of illumination was 335 (109) lx.

At TEL, telephone sets were assembled in seated, generally awkward, postures of the back and neck. The mean (*SD*) general and local level of illumination was 332 (47) lx.

At CABLE, cables were woven and prepared for other assembly units. Working postures were both seated and standing; repeated hand movements were very common (Figure 2). The mean (*SD*) general and local level of illumination was 411 (188) lx. There was no programmed work–rest cycle in any assembly unit.

Figure 1. Board assembly unit (BAU): a worker is assembling a board. His neck and back are bent and in awkward static posture.

Figure 2. Cable assembly unit (CABLE): a worker is weaving wire standing on her tiptoes. The posture of her shoulders and upper arms is considerably deviated from neutral.

2.3. Data Gathering Methods and Tools

Data were collected with an anonymous questionnaire. It consisted of two parts and covered (a) personal details (i.e., gender, age, stature, weight, daily working time, job tenure, marital status, education, second job, health and medical background) and (b) musculoskeletal problems in different body regions. The general Nordic questionnaire for the analysis of musculoskeletal symptoms was used to examine reported cases of MSDs among the study population [21]. Reported MSD symptoms were limited to the past 12 months. Additionally, the University of British Colombia (UBC) ergonomic behaviour checklist was used to evaluate working conditions and ergonomic aspects of job activities [22]. The checklist consists of four parts: physical demands, work space, organization of work and environmental conditions (lighting). All units were visited; the questionnaires and the checklist were completed by interviewing the workers and observing, respectively.

Physical exposure to work-related musculoskeletal risks was assessed with loading on the upper body assessment (LUBA) [23]. In LUBA, a score is calculated for the posture of each body part. The combined individual scores for the neck, shoulders, upper back, lower back, elbows and wrists/hands give the postural load index (PLI). PLI score shows musculoskeletal loading associated with the worker's posture. Scores under 5 indicate acceptable working posture (action category [AC] 1). For scores of 5–10, further investigation is needed and changes may be required (AC 2). For scores of 10–15, investigation and changes are required soon (AC 3). Finally, immediate investigation and changes are required for scores over 15 (AC 4) [23].

To conduct the assessment with LUBA, at each workstation, workers were videotaped during their routine job activities. The tape was reviewed in the lab; awkward postures were selected and analysed. The PLI was then calculated for each case and the level of interventional action required to reduce the risk of musculoskeletal injury due to the worker's physical loading was determined.

2.4. Data Analysis and Statistical Procedures

Upon completion of the field survey and data collection, the data were coded and transferred into the computer for further analysis. Statistical analyses were performed with SPSS version 11.5 and STATA release 7. χ^2 and analysis of variance (ANOVA) were used to assess univariate associations between PLI, individual and ergonomic variables, and reported musculoskeletal symptoms. Multiple logistic regression analysis (forward Wald) was performed for each outcome retaining individual and ergonomic variables in the models to adjust for potential confounding. In the regression analysis, if $p \leq .25$ in the χ^2 test for assessing association between the variable and reported symptoms, the variable was included in the regression model of that region [24]. For each body region, this procedure was performed for all individual and ergonomic variables. The level of significance was set at .05.

3. RESULT

Table 1 summarizes personal details of the workers in the study. Table 2 presents prevalence rates of MSD symptoms in different body regions of the assembly workers in the past 12 months. Table 2 shows that the most commonly affected regions among the workers were the lower back, knees, neck, shoulders and wrists/hands. The differences between the prevalence rates of reported symptoms among units were significant for the shoulders, elbows, wrists/hands, lower back and legs/feet ($p \leq .05$).

Based on the workers' reports, in total, there were 242 days of sick leave due to musculoskeletal problems (data not shown) in the past 12 months. Accordingly, the average sick leave

TABLE 1. Demographic Characteristics of Assembly Workers (*n* = 193)

Characteristic	*M* (*SD*)	Range
Age (years)	41.6 (5.2)	25–58
Stature (cm)	162.1 (9.8)	130–185
Weight (kg)	66.4 (10.4)	40–105
Job tenure (years)	14.4 (5.6)	1–27
Daily working time (h)	6.1 (0.8)	4–8
	%	
Gender		
female	70.5	
male	29.5	
Marital status		
single	20.2	
married	79.8	
Education		
primary	7.2	
secondary	17.2	
diploma and higher	75.6	
Second job		
yes	3.1	
no	96.9	

TABLE 2. Frequency of Reported Symptoms in Different Body Regions of Assembly Workers in the Past 12 Months (*n* = 193)

	Assembly Unit (%)					
Body Region	BAU (*n* = 69)	RAU (*n* = 68)	TEL (*n* = 9)	CABLE (*n* = 47)	Total (*n* = 193)	p^a
Neck	63.8	47.1	66.7	70.2	59.6	.062
Shoulders	60.9	44.1	44.4	68.1	56.0	.050*
Elbows	27.5	10.3	33.3	34.0	23.3	.014*
Wrists/hands	62.3	35.3	55.6	74.5	55.4	<.001*
Upper back	49.3	32.4	66.7	42.6	42.5	.097
Lower back	78.3	52.9	77.8	72.3	67.9	.011*
Thighs	31.9	17.6	44.4	31.9	27.5	.125
Knees	68.1	55.9	44.4	66.0	62.2	.299
Legs/feet	36.2	23.5	22.2	51.1	34.7	.019*

Notes. *$p \leq .05$; a = χ^2 analysis of the prevalence of the symptoms between units; BAU = board assembly unit, RAU = rack assembly unit, TEL = telephone assembly unit, CABLE = cable unit.

for each worker was 1.25 days/year (*SD* 7.1). Table 3 demonstrates the frequency of symptoms in different body regions by gender.

Table 4 presents PLI and LUBA's ACs for workers in different units. It shows that in BAU and CABLE, workers were exposed to significantly higher levels of postural loading than in the other two units. This table shows the percentage of workers in each AC. There were no cases of AC 4. Like PLI, ACs in BAU and CABLE were higher than in the two other units; therefore, they required more ergonomic solutions to be considered.

Table 5 presents significant factors associated with musculoskeletal problems. The significant factors for each body region are the result of a multiple logistic regression analysis performed to

TABLE 3. Frequency of Reported Symptoms in Different Body Regions Among Male and Female Assembly Workers in the Past 12 Months (*n* = 193)

	Gender (%)		
Body Region	Male ($n = 57$)	Female ($n = 136$)	p^a
Neck	43.9	66.2	.006*
Shoulders	40.4	62.5	.007*
Elbows	8.8	29.4	.001*
Wrists/hands	29.8	66.2	<.001*
Upper back	28.1	48.5	.010*
Lower back	49.1	75.5	.001*
Thighs	19.3	30.9	.114
Knees	49.1	67.6	.022*
Legs/feet	22.8	39.7	.031*

Notes. $^*p \leq .05$; a = χ^2 or Fisher's exact test analysis of the prevalence of the symptoms between male and female workers.

TABLE 4. Postural Load Index (PLI) and Loading on the Upper Body Assessment (LUBA) Action Categories (ACs) in Assembly Workers

		Assembly Unit (%)				
		BAU ($n = 69$)	RAU ($n = 68$)	TEL ($n = 9$)	CABLE ($n = 47$)	Total ($n = 193$)
AC	PLI[a]	8.2 ± 1.3	6.95 ± 1.87	7.1 ± 1.96	8.27 ± 1.87	7.7 ± 1.8
1 (*PLI* < 5)		1.6	10.3	11.1	4.3	5.7
2 (*PLI* = 5–10)		79.9	83.8	77.8	74.4	79.8
3 (*PLI* = 10–15)		18.5	5.9	11.1	21.3	14.5

Notes. Analysis of variance for *PLI* between units: $p < .001$; BAU = board assembly unit, RAU = rack assembly unit, TEL = telephone assembly unit, CABLE = cable unit; a = *M* ± *SD*.

TABLE 5. Models Indicating Factors with the Strongest Influence on Musculoskeletal Symptoms in Different Body Regions (*n* = 193)

	Variable Retained in Model			
Body Region	Variable	*OR*	95% CI	*p*
Neck	lighting	2.40	[1.08, 5.31]	.030
	gender	2.08	[1.07, 4.03]	.030
Shoulders	rotation	7.91	[2.04, 30.6]	.003
	gender	3.41	[1.64, 7.10]	.001
Elbows	age	7.73	[1.00, 60.09]	.050
	gender	4.10	[1.49, 11.25]	.006
Wrists/hands	gender	3.47	[1.72, 7.02]	.001
	contact stress	2.70	[1.30, 5.80]	.012
Upper back	gender	2.26	[1.14, 4.46]	.019
Lower back	gender	3.39	[1.68, 6.80]	.001
	repetition	2.13	[1.07, 4.22]	.030
Knees	gender	1.92	[1.00, 3.67]	.048
Legs/feet	gender	2.20	[1.10, 4.60]	.020

Notes. *OR* = odds ratio, CI = confidence interval.

adjust for potential confounding. The table shows that some ergonomic and individual variables are significantly associated with reported musculoskeletal symptoms in different body regions. Lighting, rotation, contact stress and repetition were the ergonomic factors retained in the regression models with *OR*s (odds ratios) over 2.1. Gender and age were the only demographic factors retained in the models. Gender was found to be a significant factor for almost all body regions with *OR* 1.92–4.10. This means that musculoskeletal symptoms were more probable among female than male workers. Age was a significant factor for elbows (*OR* 7.73).

4. DISCUSSION

The questionnaire showed that musculoskeletal symptoms were common among assembly workers. The prevalence rates for lower back, knees, neck, shoulders and wrists/hands symptoms were over 55%. This is in agreement with Choobineh, Tabatabaei, Tozihian, et al. [20]. Regarding the lower back symptoms, which had the highest rate of prevalence among the assembly workers, it is worth noting that Haynes and Williams pointed out that in jobs with more sedentary activities (such as jobs of assembly workers in the telecommunication industry), there could be a high rate of lower back problems [25]. Table 6 compares point prevalence of the symptoms among the assembly workers studied and the general Iranian population [26]. Statistical analysis (test of proportion) revealed that the differences between the prevalence rates of the symptoms in the neck, back and large joints among assembly workers and the general Iranian population were significant ($p < .001$). This comparison may indicate that jobs in telecommunication assembly lines can be considered as occupations posing a risk of developing musculoskeletal symptoms in different body regions.

TABLE 6. Comparison of Point Prevalence of Musculoskeletal Symptoms in Neck, Back and Large Joints in Assembly Workers (AW, 25–58 years old) and General Iranian Population (GI, 15–69 years old) ($p^a < .001$)

Body Region	AW (%)	GI (%)
Neck	35.2	10.2
Upper and lower back	58.5	25.3
Large joints[b]	73.6	20.0

Notes. a = test of proportion, b = including shoulders, elbows, wrists, knees and ankles.

Univariate statistical analysis revealed that prevalence rates of reported symptoms of the shoulders, elbows, wrists/hands, lower back and legs/feet were significantly different in the units studied. Based on that, comparisons indicated that reported symptoms in BAU and CABLE were more prevalent than in the two others units. This could indicate that any interventional programme for preventing or reducing musculoskeletal problems among the assembly workers should focus on reducing risk factors in BAU and CABLE.

Physical loading assessment done with LUBA showed that the level of exposure to musculoskeletal risks was considerable and high (AC 2 and 3) in 94.3% of the workers. This indicated that the jobs and working conditions in the assembly line were conducive for developing work-related MSDs. Therefore, ergonomic interventions seemed necessary to improve working conditions and decrease exposure level. LUBA also showed that workers in BAU and CABLE were exposed to significantly higher levels of postural loading with *PLI* of 8.2 ± 1.3 and 8.27 ± 1.87, respectively. This may explain the significant higher prevalence of symptoms in these units than in the other two. Similarly, in comparison with RAU and TEL, a high percentage of PLI was categorized in AC 2 and 3 in BAU and CABLE. This also indicates poor working conditions and the need for ergonomic improvements in these units.

In general, multiple logistic regression analyses of our data revealed that musculoskeletal symptoms in different body regions were significantly associated with poor lighting, rotation, local contact stress and repetition (as ergonomic factors) as well as gender and age (as individual factors). Regression analyses confirmed that after adjusting for potential confounders, poor lighting was a significant factor for symptoms in the neck region (*OR* 2.40). This is understandable since poor lighting causes workers to adopt awkward head and neck posture to meet the minimum requirement for visual activity. While no article on the direct effect of poor illumination on workplace musculoskeletal symptoms was found, some studies reported its adverse effects on workers' satisfaction and comfort. For example, Gavhed and Toomingas evaluated physical working conditions in a call centre to assess operators' comfort and symptoms. They found that low illumination was one of the physical conditions in the workplace that created dissatisfaction of comfort among nearly 74% of the operators [27]. Rotation was also found to be a significant factor for shoulder problems with a high *OR* 7.91. This was generally caused by inadequate workspace layout and poor location of items at workstations, which necessitated the rotation of the trunk and shoulders to reach for the parts. Local contact stress caused by repeated contact with the sharp edges of tools or workstations was a significant factor retained in the regression model of the wrists/hands region (*OR* 2.70). Like this study, other studies also reported that localized contact stress was associated with the development of upper limb cumulative trauma in computer users [28]. Repetition was also found to be a significant factor for lower back problem (*OR* 2.13).

In addition to ergonomic factors, consistently with univariate analysis, gender was a significant factor retained in the models for all body regions (except for the thighs) with *OR* 1.92–4.10. This indicates that the chance of MSDs among females was significantly more likely than among males. This is in agreement with the findings of other studies [14, 29, 30, 31]. For example, in their investigation on car assembly workers, Zetterberg and Öfverholm found that women were more susceptible than men to joint, tendon and nerve-related problems of the wrist and hand [19]. Age was also a significant factor for elbow symptoms with relatively high *OR* 7.73. This is in line with the findings of other studies in which association was observed between age and elbow problems [32]. For example, Landau et al. observed higher prevalence rates of head, neck, shoulder and spine symptoms among older workers as compared with their younger counterparts in assembly jobs of an automotive industry [18].

Regarding the cross-sectional design of the study and collecting data through self-reporting, the findings of this study should be interpreted with caution. Self-report methodology may suffer from some weak points, namely, difficulty in recall, denial or deception. In this study, however, by limiting the recall period for reported symptoms to the past 12 months, the time over which data needed to be recalled was restricted. Finally, since the analysis was limited to currently employed workers, workers who had left jobs due to musculoskeletal problems could inadvertently have been excluded from the study and the healthy worker effect could occur. Thus, the data may underestimate the prevalence of reported symptoms and the association of ergonomic and individual factors with MSDs.

Based on the results of this study, to improve working conditions and reduce postural loading on assembly workers, the following ergonomic corrective measures were recommended:

- providing an adequate level of illumination with uniform distribution at workstations;
- optimizing workspace layout to cut down on the need for rotation;
- rounding edges of equipment or workstations and padding tools or workstations;
- devising an appropriate work–rest cycle;
- training workers in work methods to avoid MSD risk factors.

5. CONCLUSION

The findings of this study collectively indicated that workers' postural loading was considerable and high. Taking corrective measures to reduce the risk level seemed essential. In this respect, BAU and CABLE were a priority. Any ergonomic interventional programme at the workplace should particularly focus on adequate lighting, optimal workspace layout, elimination of contact stress, suitable work–rest cycles and training workers.

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