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Musculoskeletal Risk Assessment in Small Furniture Manufacturing Workshops

Naser Hashemi Nejad

School of Health, Kerman University of Medical Sciences, Kerman, I.R. Iran

Alireza Choobineh

Research Center for Health Sciences, Shiraz University of Medical Sciences, Shiraz, I.R. Iran

Hoda Rahimifard

School of Health, Qom University of Medical Sciences, Qom, I.R. Iran

Hamid Reza Haidari

School of Health, Qom University of Medical Sciences, Qom, I.R. Iran

Sayed Hamid Reza Tabatabaei

School of Health and Nutrition, Shiraz University of Medical Sciences, Shiraz, I.R. Iran

*In Iran, furniture is mainly manufactured in small workshops, where most activities are performed manually. This study was conducted among workers of furniture workshops to determine prevalence of musculoskeletal symptoms and to assess ergonomic working conditions to identify major risk factors associated with musculoskeletal symptoms. In this study, 410 randomly selected furniture workers participated. The Nordic questionnaire and an ergonomics checklist consisting of 6 sections were used as data collection tools. An index was calculated for each section of the checklist. Action categories indicating the priority of corrective measures were also defined. The highest prevalence of symptoms was reported in the knees (39%), lower back (35.6%) and wrists/hands (29.5%). It was found that manual material handling, poor workstation design and awkward working postures were associated with the reported symptoms in these regions (*OR *1.77–4.52). Poor general working conditions and work organization showed association as well. Any interventional measures should focus on these areas.*

musculoskeletal disorders ergonomics assessment ergonomics checklist furniture industry

1. INTRODUCTION

Musculoskeletal disorders (MSDs) are a major cause of occupational injury in the developed and industrially developing countries [1, 2, 3, 4]. Risk factors have been found to include workplace activities such as heavy lifting, repetitive tasks and awkward working postures [5, 6], while demographic characteristics (i.e., age, gender, job tenure, etc.) and psychosocial factors are also known to be important predictive variables [7, 8, 9, 10, 11, 12]. In industrially developing countries, the problems of workplace injuries are serious [4]. Poor working conditions and no effective

Correspondence should be sent to Hoda Rahimifard, Department of Occupational Health, School of Health, Qom University of Medical Sciences, Qom, I.R. Iran. E-mail: rahimifard@muq.ac.ir.

work injury prevention programs in these countries have resulted in very high rates of MSDs [13].

Furniture manufacturing workers are exposed to many MSD occupational risk factors [14]. Products manufactured in furniture facilities are heavy, bulky and awkward, which necessitates much manual work [15]. Heavy lifting, force exertion, repetitive motions, awkward and static working postures, vibration, contact stress, pinch grips and environmental factors are recognized as the main factors associated with work-related MSDs in the furniture industry [16]. Additionally, a high level of noise and inadequate lighting in furniture factories have been reported [17].

In Iran, furniture is mainly manufactured in small workshops, categorized as small-scale industry, where 2–5 workers are employed and engaged in different stages of production processes. In these workshops, many activities involve manpower and job activities are labor-intensive. Physical activities such as manual material handling (MMH) (e.g., heavy load lifting, lowering, carrying, pulling and pushing), awkward postures and poor working conditions are very common (Figure 1). In this situation, high rates of work-related MSDs are expected.

There are few studies specifically related to work-related MSDs among small furniture manufacturing workshops to report the prevalence of musculoskeletal symptoms and assess physical exposure to musculoskeletal risk. Therefore, this study was conducted in these workshops (a) to determine the prevalence of musculoskeletal symptoms among furniture workers and (b) to assess ergonomic working conditions to identify major risk factors associated with musculoskeletal symptoms. The results of this study can be an appropriate basis for planning and implementing interventional ergonomics programs in the workplace and improving workers' health in small furniture workshops.

Figure 1. Working conditions in a furniture manufacturing workshop. *Notes.* All working postures are awkward and deviated from neutral: (a) woodworking, (b) joining wood pieces, (c) abrading, (c) padding.

2. METHODS

This cross-sectional study was conducted from February 2008 to March 2009 in Qom, an important furniture manufacturing center in Iran with 683 active workshops.

2.1. Subjects and Sample Size

The sample size was determined with reference to Mirmohammadi, Nasl Seraji, Shahtaheri, et al.'s results [18], in which the prevalence rate of musculoskeletal symptoms in an Iranian furniture manufacturing enterprise was reported to be 50% (p = .50). Regarding this and taking confidence level of 95% and d = 5% into consideration, the sample size was calculated to be 385 workers. As nearly 5% of missing data could be expected, the sample size reached 410 subjects, who were randomly selected from a list provided by the Furniture Manufacturers Union in Qom. All subjects were male with at least one year of job tenure.

2.2. Data Gathering Tools

An anonymous self-administered questionnaire was used to collect the required data from each subject. The questionnaire consisted of two parts: (a) personal details (including age, job tenure, daily working time and education) and (b) the Persian version of the general Nordic Questionnaire of musculoskeletal symptoms to examine reported cases of musculoskeletal symptoms in different body regions among the study population [19]. Reported musculoskeletal symptoms were limited to the past 12 months. Each participant received the questionnaire in person in his workplace.

To assess ergonomic working conditions in the furniture workshops, a comprehensive ergonomics checklist was developed. The checklist was structured to cover ergonomic problems that might exist in furniture workshops. The checklist integrated the available knowledge on this issue and provided a systematic ergonomics assessment tool for furniture workshops. It could also be used to provide a list of priorities for improving working conditions.

The checklist consisted of six sections including

- GWC (general working conditions), i.e., noise, illumination and climate;
- WO (work organization), i.e., work–rest cycle, housekeeping, training, personal protective equipment (PPE), machinery maintenance program, overtime, etc.;
- HT (hand tools), i.e., excessive vibration, excessive force, handle size and design, weight, contact stress, tools powered, wrist posture, etc.;
- MMH, i.e., load weight, movement distance, frequency of handling, lifting, pulling, pushing, carrying, handholds, mechanical aids, walking surface, etc.;
- WS (workstation design), i.e., workspace room, adjustability, seat, reach envelope, anti-fatigue mat, posture variation, etc.;
- WP (working posture), i.e., bending or twisting of the back and wrist, arm and shoulder extension/flexion, crouching, kneeling, static muscle loading, etc.

Those were the criteria of particular importance for assessment. In the process of developing the checklist, various references were consulted [16, 20, 21, 22, 23, 24]. The checklist had 101 items in the six sections mentioned in this section.

The researchers observed all items of the checklist at the subjects' workstations. Each item was assessed as either *provided* (yes; score: 1) or *not provided* (no; score: 0).

The total ergonomics (*TE*) index was calculated as a percentage of all provided items in the checklist. Additionally, an index was calculated for each section of the checklist to identify the major sources of problems and ergonomic bottlenecks in the workplace. The formulas used to calculate the indices were as follows:

$$GWC = (X_1 \times 100)/10,$$

where X_1 = sum of the number of provided items in the GWC section (there were 10 items in this section).

$$WO = (X_2 \times 100)/(17 - NA_2),$$

where X_2 = sum of the number of provided items in the WO section (17 items), NA_2 = number of nonapplicable items in this section.

$$HT = (X_3 \times 100)/[(20 - NA_3)_1 + \ldots + (20 - NA_3)_n],$$

where X_3 = sum of the number of provided items in the HT section for all hand tools used by the worker (20 items), n = number of hand tools used by the worker, NA_3 = number of nonapplicable items for each hand tools in this section.

$$MMH = (X_4 \times 100)/(20 - NA_4),$$

where X_4 = sum of the number of provided items in the MMH section (20 items), NA_4 = number of nonapplicable items in this section.

$$WS = (X_5 \times 100)/[(13 - NA_5)_1 + \ldots + (13 - NA_5)_n],$$

where X_5 = sum of the number of provided items in the WS section for all workstations the worker worked at (13 items), n = number of workstations in which a worker performed tasks, NA_5 = number of nonapplicable items in this section.

$$WP\ Index = (X_6 \times 100)/[N_3 \times (21 - NA_6)],$$

where X_6 = sum of the number of provided items in the WP section (21 items), N_3 = number of WPs the worker adopted while doing his major tasks, NA_6 = number of nonapplicable items in this section.

$$TE = [(X_1 + X_2 + X_3 + X_4 + X_5 + X_6) \times 100]/\{10 + (17 - NA_2) + [(20 - NA_3)_1 + \ldots + (20 - NA_3)_n] + (20 - NA_4) + [(13 - NA_5)_1 + \ldots + (13 - NA_5)_n] + [N_3 \times (21 - NA_6)]\}.$$

The indices could vary from 0% to 100%. A low and a high percentage reflected poor and appropriate ergonomic conditions, respectively, in the corresponding index.

After calculating the indices, each one was interpreted in accordance to action categories (ACs): AC 1 = further investigation is needed, corrective measures are required soon, attention should be focused on priorities; AC 2 = working conditions are acceptable, but attention should be focused on priorities.

Each index was categorized based on the cut-off point calculated with the receiver operating characteristics (ROC) curve methodology [25]. The cut-off points were between 0% and 100%; they were determined based on the prevalence rate of musculoskeletal symptoms. Table 1 presents ACs as well as cut-off points for each assessment index.

To measure the reliability of the checklist, a pilot study was carried out on 30 furniture workers, in which two observers simultaneously observed and assessed the working conditions with the checklist [26]. The results showed a high percentage of identical responses between the raters and, therefore, indicated acceptable inter-rater reliability.

2.3. Data Analysis and Statistical Procedures

Statistical analyses were performed with SPSS version 12.0; the χ^2 test was used to assess univariate associations between ACs and reported musculoskeletal symptoms. The independent sample t test was used to compare means of assessment indices in groups with and without symptoms. The test of proportion was also used to compare point prevalence of musculoskeletal symptoms in the general Iranian male population and the furniture workers studied. The odds ratio (*OR*) was calculated where appropriate. The level of significance was set at 5%.

TABLE 1. Action Categories (AC) and Cut-Off Points for Assessment Indices

	Assessment Index (%)						
AC	***GWC***	**WO**	***HT***	***MMH***	***WS***	***WP***	***TE***
1	0–64.99	0–34.51	0–87.34	0–62.12	0–39.35	0–57.07	0–63.16
2	65–100	34.52–100	87.35–100	62.13–100	39.36–100	57.08–100	63.17–100

Notes. 1 = corrective measures are required, 2 = working conditions are acceptable; *GWC* = general working conditions index, *WO* = work organization index, *HT* = hand tools index, *MMH* = manual material handling index, *WS* = workstation design index, *WP* = working posture index, *TE* = total ergonomics index.

2. RESULTS

The means (*SD*) of age (years), job tenure (years) and daily working time (hours) in the study population were 29.82 (8.96), 11.78 (8.67) and 9.1 (1.26), respectively. Most participants (72.7%) had elementary education. Table 2 presents the prevalence of musculoskeletal symptoms in different body regions of the workers in the past 12 months. Table 2 shows that the most commonly affected regions were the knees, lower back and wrists/hands.

TABLE 2. Reported Symptoms in Different Body Regions in the Past 12 Months (*n* = 410)

Body Region	No.	(%)
Neck	75	(18.3)
Shoulders	93	(22.7)
Elbows	28	(6.8)
Wrists/hands	121	(29.5)
Upper back	58	(14.1)
Lower back	146	(35.6)
Thighs	51	(12.4)
Knees	160	(39.0)
Legs/feet	78	(19.0)

Table 3 shows the results of an ergonomics assessment of the working conditions in the workshops studied. As seen, *WO*, *WS* and *WP* indices had the lowest means indicating poor conditions in these areas.

TABLE 3. Assessment Indices for Workstations (*n* = 410)

Assessment Index	*M*	*SD*
GWC	62.8	14.37
WO	34.55	6.24
HT	84.76	5.17
MMH	65.11	9.22
WS	39.6	6.46
WP	56.51	4.42
TE	64.14	3.79

Notes. A lower score indicates poorer working conditions; *GWC* = general working conditions index, *WO* = work organization index, *HT* = hand tools index, *MMH* = manual material handling index, *WS* = workstation design index, *WP* = working posture index, *TE* = total ergonomics index.

Table 4 presents the frequency of assessment indices in each AC. The main ergonomic problems in the workshops studied seemed to originate from poor GWC, WO and WPs as the highest frequency in AC 1 was observed in these areas. In 39.5% of the observed cases, the *TE* index was in AC 1 indicating overall inappropriate working conditions in these cases.

TABLE 4. Assessment Indices in Each Action Category (*n* = 410)

	AC 1		AC 2	
Assessment Index	No.	(%)	No.	(%)
GWC	268	(65.4)	142	(34.6)
WO	210	(51.2)	200	(48.8)
HT	142	(34.6)	268	(65.4)
MMH	136	(33.2)	274	(66.8)
WS	178	(43.4)	232	(56.4)
WP	206	(50.2)	204	(49.8)
TE	162	(39.5)	248	(60.5)

Notes. AC = action category; 1 = corrective measures are required, 2 = working conditions are acceptable; *GWC* = general working conditions index, *WO* = work organization index, *HT* = hand tools index, *MMH* = manual material handling index, *WS* = workstation design index, *WP* = working posture index, *TE* = total ergonomics index.

Table 5 depicts *TE* index values for workers with and without symptoms in different body regions. As Table 5 shows, *TE* index means among the workers who reported symptoms in different body regions were significantly lower than those of the other group ($p < .05$, with the exception for knees). This indicates that workers without symptoms in a particular body region had a greater *TE* index and, therefore, experienced better working conditions.

Table 6 displays the prevalence of reported musculoskeletal symptoms in different body regions among the workers based on the AC determined by the *TE* index. As shown, the prevalence of symptoms in all body regions was higher when AC = 1 as compared with that of the other group (AC = 2). Table 6 presents *OR*s, too; *OR*s ranged from 2.15 to 6.36 for different body regions indicating that the chance of musculoskeletal symptoms occurring among subjects categorized in the group of AC = 1 was at least 2.15 times higher than in the other group.

Further statistical analysis determined musculoskeletal symptoms associated factors in the knees, lower back and wrists/hands, which had the high-

TABLE 5. Total Ergonomics (*TE*) Index in Different Body Regions Among Workers With and Without Reported Symptoms (*n* = 410)

	TE						
	With Symptoms			Without Symptoms			
Body Region	***M***	***SD***	***n***	***M***	***SD***	***n***	***p*** [a]
Neck	62.56	3.87	75	64.50	3.68	335	<.001
Shoulders	62.88	3.96	93	64.51	3.66	317	<.001
Elbows	60.54	3.62	28	64.41	3.67	382	<.001
Wrists/hands	62.62	3.80	121	64.78	3.60	289	<.001
Upper back	62.01	3.56	58	64.49	3.71	352	<.001
Lower back	62.30	3.51	146	65.16	3.55	264	<.001
Thighs	61.78	3.57	51	64.48	3.70	359	<.001
Knees	63.73	4.13	160	64.41	3.54	250	.090
Legs/feet	63.03	3.83	78	64.40	3.74	332	.040

Notes. a = independent *t* test between the 2 groups; a lower score presents poorer working conditions.

TABLE 6. Reported Symptoms in Different Body Regions Based on Action Category (*n* = 410)

	AC 1	AC 2		
Body Region	***n* (%)**	***n* (%)**	***OR***	***p*** [a]
Neck				
with symptoms (*n* = 75)	46 (28.4)	29 (11.7)	3.01	<.001
without symptoms (*n* = 335)	116 (71.6)	219 (88.3)		
Shoulders				
with symptoms (*n* = 93)	51(31.5)	42 (16.9)	2.26	.001
without symptoms (*n* = 317)	111 (68.5)	206 (83.1)		
Elbows				
with symptoms (*n* = 28)	22 (13.6)	6 (2.4)	6.36	<.001
without symptoms (*n* = 382)	140 (86.4)	242 (97.6)		
Wrists/hands				
with symptoms (*n* = 121)	71 (43.8)	50 (20.0)	3.11	<.001
without symptoms (*n* = 289)	91 (56.2)	198 (80.0)		
Upper back				
with symptoms (*n* = 58)	35 (21.6)	23 (9.3)	4.53	.001
without symptoms (*n* = 352)	127 (78.4)	225 (90.7)		
Lower back				
with symptoms (*n* = 146)	91 (56.2)	55 (22.2)	4.52	<.001
without symptoms (*n* = 264)	71 (43.8)	193 (77.8)		
Thighs				
with symptoms (*n* = 51)	35 (21.6)	16 (6.4)	4.01	<.001
without symptoms (*n* = 359)	127 (78.4)	232 (93.6)		
Knees				
with symptoms (*n* = 160)	81 (50.0)	79 (31.9)	2.15	<.001
without symptoms (*n* = 250)	81 (50.0)	169 (68.1)		
Legs/feet				
with symptoms (*n* = 78)	45 (27.8)	33 (13.3)	2.52	<.001
without symptoms (*n* = 332)	117 (72.2)	215 (86.7)		

Notes. AC = action category; 1 = corrective measures are required, 2 = working conditions are acceptable; *OR* = odds ratio; a = χ^2 analysis of the prevalence of symptoms between action category groups.

est prevalence rates of reported symptoms (Table 7). As shown, for the knees, *MMH*, *WS*, *WP* and *TE* were associated with the reported symptoms (*OR* 1.77–2.15). This meant that the chance of symptoms in the knees occurring among individuals categorized in the group of AC = 1 in those indices was 1.77–2.15 times higher than in the other group. All indices, except for *HT*, were found to be associated with lower back symptoms (*OR* 1.66–4.53). For the wrists/hands, *WO*, *MMH*, *WS*, *WP* and *TE* were associated with reported symptoms (*OR* 1.76–3.38).

To prepare a list of corrective measures necessary to improve the working conditions in the furniture workshops studied, the items in each section of the checklist were examined. On that basis, the main ergonomics shortcomings were identified:

- GWC: dirty windows and poor illumination, inappropriate climate and noise pollution in the workshops;
- WO: no training program for proper work practices, no preventive maintenance program for tools and machines, no PPE or use of inappropriate PPE, no safety instructions and protocols to perform the operation, overtime, no work pause and proper work–rest cycle;
- MMH: no mechanical lifting aides, lifting below knuckle height and above shoulder height, not enough room to maneuver, no team approach to lifting heavy loads;
- WS: no adjustable workstation, no support for feet and arms at workstations, no cushioned floor mats for workers required to stand for long periods;
- WP: bending/twisting of the back, bent/twisted neck, raised elbows, flexed/extended shoulders, twisted/deviated wrists, kneeling position.

3. DISCUSSION

The questionnaire showed that the most commonly affected regions among the subjects were the knees (39%), lower back (35.6%) and wrists/hands (29.5%). The results revealed that *WO*, *WS* and *WP* had the lowest means (Table 3). This indicates poor conditions in these areas necessitating adequate ergonomics solutions. Nearly consistent with Table 3, as Table 4 shows, *GWC*, *WO*, *WS* and *WP* had the highest frequency in AC 1. So, to improve working conditions, corrective measures should focus on these indices.

The results demonstrated that the mean of *TE* among those who reported musculoskeletal symptoms in almost all body regions (except for the knees) was lower than in those without symptoms (Table 5). This implies that an improvement in overall working conditions, which would increase the mean of *TE*, might result in a decrease in the prevalence of musculoskeletal symptoms.

TABLE 7. Musculoskeletal Symptoms Associated Factors in Knees, Lower Back and Wrists/Hands Regions (*n* = 410)

	Body Region					
	Knees		Lower Back		Wrists/Hands	
Assessment Index	*OR*	*p*[a]	*OR*	*p*[a]	*OR*	*p*[a]
GWC	—	>.050	1.66	.030	—	>.050
WO	—	>.050	2.50	<.001	1.76	<.010
HT	—	>.050	—	>.050	—	>.050
MMH	2.08	.001	4.52	<.001	2.38	<.001
WS	1.77	.006	2.82	<.001	2.55	<.001
WP	2.15	<.001	4.53	<.001	3.38	<.001
TE	2.15	<.001	4.52	<.001	3.11	<.001

Notes. OR = odds ratio; a = χ^2 analysis of the prevalence of symptoms between action category groups; *GWC* = general working conditions index, *WO* = work organization index, *HT* = hand tools index, *MMH* = manual material handling index, *WS* = workstation design index, *WP* = working posture index, *TE* = total ergonomics index.

According to Table 6, the ergonomics conditions of the workshops were a significant factor ($p \leq .001$) for the occurrence of musculoskeletal symptoms in all body regions (*OR* 2.15–6.36).

The results revealed that *MMH*, *WS* and *WP* were the main significant associated indices for reported symptoms in the knees, lower back and wrists/hands (Table 7). *WP* was the most effective factor in the occurrence of symptoms in these regions as it had the highest *OR*s. This is in accord with the findings of other studies in which awkward WPs were found to be the main associated factor for reported musculoskeletal symptoms [27, 28, 29, 30]. *MMH* was also shown to have association with symptoms in the knees, lower back and wrists/hands, with *OR*s of 2.08, 4.52 and 2.38, respectively. This is in line with the findings of other studies in which lower back problems among workers involved in MMH tasks were reported to be much more frequent than in workers not involved in MMH activities [31]. Similarly, according to Paskiewicz and Fathallah, MMH was the main reason of the high prevalence rate of lower back problems in the furniture moving industry [32]. *WS* was also found to be associated with symptoms in these regions. Since postural problems appear to be largely caused by improperly designed and ill arranged workstation [33], to improve working conditions, designing ergonomic workstations in furniture workshops should be paid adequate attention. *GWC* was also associated with reported symptoms in the lower back (*OR* 1.66). Additionally, *WO* had association with lower back and wrists/hands symptoms (*OR* 2.5 and 1.76, respectively). This indicates that besides MMH, WS and WP, GWC and WO require improvement in the furniture workshops and have to be considered in an interventional corrective ergonomics program to reduce the prevalence of musculoskeletal symptoms.

The findings revealed that the special-purpose checklist and its assessment indices developed in this study was an appropriate tool for investigating ergonomics conditions in furniture workshops as there were significant associations between reported symptoms and the means of assessment indices. Some other researchers have also used ergonomics checklists to identify and evaluate musculoskeletal risk factors in the workplace and reported their appropriateness for ergonomics assessment [21, 34, 35, 36].

4. CONCLUSIONS

The highest rates of symptoms were reported in the knees, lower back and wrists/hands. The working conditions in the workshops studied were inappropriate and needed corrections. Most problems originated from poor GWC, WO, MMH, inappropriate WS and awkward WPs. Therefore, any interventional ergonomic measures should focus on these problems.

The checklist and assessment indices presented in this paper can be used to assess working conditions in furniture workshops as the first step in identifying major ergonomic problems, and setting priorities and corrective measures. Using this checklist for ergonomics assessment revealed that it was an effective tool in identifying ergonomic risk in furniture workshops.

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