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Musculoskeletal Symptoms as Related to Ergonomic Factors in Iranian Hand-Woven Carpet Industry and General Guidelines for Workstation Design

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Carpet weaving is a high risk occupation for developing musculoskeletal disorders (MSDs). The objectives of the present study, which was carried out in the Iranian hand-woven carpet industry, were determination of the prevalence of MSD symptoms, identification of major factors associated with MSD symptoms and development of guidelines for workstation design. 1,439 randomly selected weavers participated in this study. A questionnaire was used to collect data on MSD symptoms. The results revealed that the prevalence rates for symptoms in different body regions were high as compared to the general Iranian population (for neck, back and large joints, $p < .0001$*). The results of multivariate analyses showed that major ergonomic factors associated with musculoskeletal symptoms were loom type, working posture, daily working time and seat type. Based on the results, some general guidelines for designing weaving workstations were developed. A prototype test showed that the new workstation was acceptable for subject tests and that it improved working posture.*

MSDs in small-scale industries posture assessment in carpet hand weaving operation
MSDs in industrially developing countries (IDCs) weaving workstation design

1. INTRODUCTION

Musculoskeletal disorders (MSDs) are a common health problem and a major cause of disability throughout the world. The economic loss due to such disorders affects not only the individual but also the organization and the society as a whole [1]. At present, MSDs are one of the most important problems ergonomists encounter in the workplace all over the world [2]. In many countries, prevention of work-related musculoskeletal disorders (WMSDs) has become a national priority [3].

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WMSDs are a worldwide concern. They are present among both Industrialized Countries (ICs) and Industrially Developing Countries (IDCs). In IDCs, the problems of workplace injuries are extremely serious [4]. Poor working conditions and the absence of effective work injury prevention programs in IDCs have resulted in a very high rate of MSDs [5].

In IDCs, small-scale industries comprise a high percentage of all factories and manufacturing establishments. The preponderance of small-scale industries and their employment of a substantial percentage of the work-force in IDCs necessitate greater attention towards the health and safety problems in this sector [6]. A reduction in MSDs and an improvement in working conditions of small-scale industries' workers of IDCs will have a considerable effect on promoting and sustaining the quality of people's life and will result in higher productivity.

Carpet hand weaving is a common practice in different countries such as Iran, China, Turkey, India, Pakistan, Russia, Egypt, Nepal and Afghanistan. In Iran, hand-woven carpets are produced nearly always in home-based workshops categorized as an informal small-scale industry. Hand-woven carpets are Iranian most important non-oil exported goods and they have an outstanding place in the country's economy as they account for 1% of the Gross National Product [7] and employment. In Iran, there are nearly 2.2 million full-time and part-time weavers [8] and about 8.5 million people directly or indirectly live from the hand-woven carpet industry [9].

Carpet weaving is one of the most tedious professions, requiring long hours of static work [10]. It is also a high risk occupation for developing MSDs as awkward posture, repetitive movements, contact stress, long working time and no rest pauses are common [11].

In spite of the national importance of the hand-woven carpet industry in Iran and its potential impact on the overall economy of the country, there have been few ergonomics studies of weavers' work. The present study has, therefore, been carried out in this industry with the objectives of (a) determining the prevalence of musculoskeletal symptoms in different body regions of carpet weavers, (b) assessing the working posture and carpet weaving workstations, (c) identifying major factors associated with MSD symptoms in carpet weaving occupations and (d) developing guidelines for designing weaving workstations.

2. MATERIALS AND METHODS

In this cross-sectional study, weavers' individual characteristics, workshop details and musculoskeletal symptoms in active weaving workshops in rural and urban districts of nine Iranian provinces were surveyed. Working posture and weaving workstations were ergonomically assessed. In each province, up to 175 weavers were randomly selected from the corresponding list of workshops. In total, 1,439 weavers participated in this study.

A questionnaire and a checklist were used to collect required data from each sample and each workstation, respectively. The questionnaire consisted of two parts:

1. Workshop details (including type of workshop, number of weavers, type of loom, type of knot, temperature, and illumination) and personal details (including age, gender, job tenure, daily working time, marital status, number of children, educational level, handedness and medical background).
2. Translated General Nordic Questionnaire [12].

The checklist consisted of two parts:

1. Weaving posture assessment checklist: this was based on RULA technique [13] in which arm, neck, trunk, and leg postures were taken into consideration.
2. Weaving workstation assessment checklist: it consisted of points related to leg position, leg space, loom angle, type of seat and its padding.

All workshops were visited and the questionnaires were completed by interviewing

the weavers. Upon questionnaire completion, the researcher asked the weaver to start weaving. After a thorough observation, the researcher marked the checklist. Observations were made from the right side of the weavers' bodies.

In each province, industrial hygienists from the Occupational Health Department of the Province Health Center, Ministry of Health did the research. They were trained and informed about the study's structure, its goals and data collection instruments through an ergonomics workshop. In all, 39 industrial hygienists took part in the field data collection stage.

In order to estimate the reliability of the responses to questions in the questionnaire, the test-retest method was applied [14] on 5% of the study population. Upon completion of the field survey and data collection, data was coded and transferred into the computer for further analysis. Statistical analyses were performed using SPSS and STATA. The chi-square test was used to assess univariate associations between individual and ergonomic variables and reported musculoskeletal symptoms. Multiple logistic regression analysis was performed for each outcome retaining the individual and ergonomic variables in the models to adjust for potential confounding.

3. RESULTS

Table 1 summarizes personal details of the weavers and some characteristics of the workshops. Most weavers were female. More than half of the weavers worked 6 to 7 days a week (67%), four seasons a year (73.9%). Most weavers worked at vertical looms (85.7%) and used Persian knots in their weaving (81.7%). The overwhelming percentage of carpet production (92.3%) was produced in home-based workshops.

Table 2 presents the prevalence of MSD symptoms in different body regions of weavers during the last 12 months. As Table 2 shows, shoulders (47.8%), lower back (45.2%), wrists (38.2%), upper back (37.7%), neck (35.2%) and knees (34.6%) were the most commonly affected regions among the weavers.

Based on the weavers' reports, during the last 12 months there, in total, had 15,368 days of sick leave due to musculoskeletal problems. Accordingly, the average sick leave for each weaver was 10.68 days/year (*SD* = 31.3 days).

An assessment of the weavers' work showed that a high percentage of observed postures of the upper arm, neck and trunk deviated from the neutral posture (Table 3). In 70.3% of all cases, leg posture obtained a score of 2 indicating that weavers sat on the ground or on a piece of lumber in a cross-legged or folded-knee position (Figures 1 and 2). Working posture assessment indicated

Figure 1. Weavers are weaving at a vertical loom. They are sitting on a piece of lumber in a cross-legged position.

Figure 2. A woman is working at a horizontal loom. The back is bent excessively; her knees are folded and the overall body posture dramatically deviates from the neutral.

that horizontal looms caused a more deviated body posture such that in all cases neck, trunk and leg postures were non-neutral (Table 3). Figure 2 shows a typical working posture adopted by weavers while working at horizontal looms.

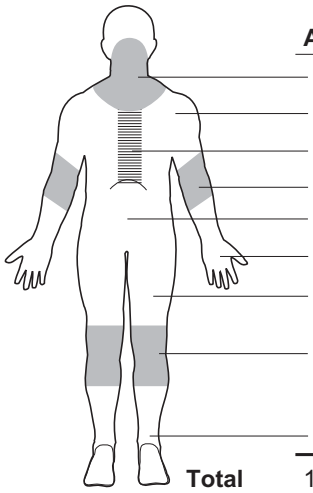
Table 4 presents some details on a weaving workstation with vertical looms. Only 0.4% of these workstations were equipped with a chair. In 77.6% of the cases the seats were pieces of lumber with no good support and back rest. In

TABLE 1. Some Personal Information on Participants and Workshops (*n* = 1,439)

Gender (%)	Female	98
	Male	2
Age (years)	*M* (*SD*)	31.21 (11.22)
	min–max	13–81
Age at which began weaving (years)	*M* (*SD*)	14.43 (6.58)
	min–max	4–49
Job tenure (years)	*M* (*SD*)	16.83 (12.78)
	min–max	1–75
Daily working time (hrs)	*M* (*SD*)	7.33 (2.6)
	min–max	1–16
Weekly working days (%)	≤5	33
	>5	67
Working time (%)	Flexible	81.4
	Fixed or shift	18.6
Marital status (%)	Single	33.2
	Married	66.8
Number of children (%)	≤3	48.2
	>3	51.8
Handedness (%)	Right	92.5
	Left	7.5
Education (%)	Illiterate	21.7
	Primary	58.4
	Intermediate	14.1
	Diploma and higher	5.9
Main job (%)	Weaving	89
	Agriculture	11
Knots* (%)	Persian	81.7
	Turkish	18.3
Loom (%)	Horizontal	14.3
	Vertical	85.7
Workshop (%)	Home-based rural	81.6
	Complex rural	1.0
	Home-based urban	10.7
	Complex urban	6.7
Production system (%)	Independent production	49.7
	Contract production	50.3

Notes. ***—**There are two methods used for making knots in hand-weaving operations. The Turkish knot is used in all typical Turkish carpets. It makes a carpet stronger and more durable, while the Persian knot largely facilitates the weaving of varied patterns. However, once a carpet is finished, it is difficult to determine the knotting system.

TABLE 2. Frequency of Reported Symptoms in Different Body Regions of Weavers in the 12 Months Prior to the Study



	All Weavers (%)	Horizontal Loom Users(%)	Vertical Loom Users (%)	*P*-value*
	35.2	52.7	32.1	<.0001
	47.8	51.7	46.9	>.0500
	37.7	59.1	34.1	<.0001
	19.2	21.6	18.6	>.0500
	45.2	63.3	42.2	<.0001
	38.2	48.3	36.5	<.0001
	16.0	29.1	13.7	<.0001
	34.6	42.0	33.4	.0170
	23.7	38.7	21.2	<.0001
Total	1439	205	1234	

Notes. *Chi-square analysis of the prevalence of the symptoms between vertical and horizontal loom users.

TABLE 3. Working Posture Assessment in Weaving Operations

	Working Posture (%)					
	All Weavers		Horizontal Loom Users		Vertical Loom Users	
Body Region	**Neutral***	**Non-Neutral****	**Neutral***	**Non-Neutral****	**Neutral***	**Non-Neutral****
Upper arm	12.5	87.5	22.9	77.1	10.7	89.3
Lower arm	41.3	58.7	87.8	12.2	33.8	66.2
Neck	15.1	84.9	—	100	17.7	82.3
Trunk	13.6	86.4	—	100	15.9	84.1
Leg	29.7	70.3	—	100	34.9	65.1

Notes. *—score 1, **—score 2 or higher.

TABLE 4. Results of Points Checked in Workstation Assessment (Vertical Looms)

Points	Items	*n*	%
Seat type	Chair	5	0.4
	Bench	97	7.9
	Lumber	951	77.6
	Ground	172	14.1
	Total	**1225**	**100**
Leg position	Well supported	311	25.6
	Dangling	197	16.2
	Cross-legged	706	58.2
	Total	**1214**	**100**
Seat padding	Padded	744	61
	Unpadded	475	39
	Total	**1219**	**100**
Sufficient leg space	Yes	678	55.3
	No	548	44.7
	Total	**1226**	**100**

most cases (74.4%), legs were in a poor position (dangling, cross-legged or folded). Nearly in half of the workstations there was not sufficient clearance under the loom for leg movement and shifting postural stress over different parts of lower extremities.

No adjustment mechanism was observed in the components of the weaving workstations including seat, loom and weaving heights in any of the workshops studied.

4. DISCUSSION

This study has resulted in a more detailed knowledge on the occurrence of musculoskeletal complaints in carpet weavers and on the features of their workstations. In the following paragraphs, particularly significant results are discussed.

4.1. Prevalence of Musculoskeletal Symptoms

The questionnaire showed that musculoskeletal symptoms were common among weavers. Some kind of musculoskeletal symptoms had been experienced during the last 12 months by 81.17% of the weavers. A comparison of the results of this study with the results of the National Health Survey of Iran [15] revealed that the differences between the prevalence of musculoskeletal problems were significant (Table 5). This indicates that carpet weaving can be considered as a high risk occupation for developing musculoskeletal disorders.

Analyses demonstrated that the prevalence rates of musculoskeletal symptoms of different body regions of weavers were significantly different ($p < .05$). Based on the results of this study, in the carpet weaving occupation, shoulders, the back, wrists, the neck and knees are at a high risk of musculoskeletal problems and should, therefore, be considered a high priority in interventional ergonomic programs.

4.2. Lost Working Days

Musculoskeletal problems in the study population caused a notable rate of sick leave in the last 12 months (15,368 days).With regards to the daily working time of 7.33 hrs (Table 1), this rate of sick leave is equal to 54.16 Full Time Equivalent (FTE), where FTE is considered to be 2,080 annual working hours of a worker [16]. This shows that 3.76% of the workforce who participated in this study were not productive and could not work in the last year due to musculoskeletal problems. Generalizing this feature to the total weavers' population of Iran (2.2 million) yields 23,496,000 lost working days during the past year, which equals to 82,800 FTE. This estimation indicates that, regardless of indirect costs and negative effects of musculoskeletal problems on product quality, neglecting ergonomic considerations in this small-scale industry has caused pronounced direct costs in the form of notable lost working days.

4.3. Factors Associated With Musculoskeletal Symptoms

In general, statistical analyses showed that musculoskeletal symptoms in different body regions (neck, shoulders, legs, etc.) were significantly associated with loom type, working

TABLE 5. Comparison of Point Prevalence of Musculoskeletal Symptoms in Neck, Back and Large Joints in General Iranian Population and the Study Population

Body Region	Study Population (%) (age = 15–69)	General Iranian Population (%) (age = 15–69)	*P*-value*
Neck	22.80	10.20	<.0001
Upper and lower back	34.64	25.29	<.0001
Large joints†	56.91	20.00	<.0001

Notes. *—test of proportion; †—including shoulders, elbows, wrists, knees and ankles.

posture, daily working time, seat type and type of knots (so-called ergonomic factors), as well as, age, gender, marital status and job tenure (so-called individual factors). Table 6 presents significant factors associated with musculoskeletal problems for each body region. The significant factors for each body region are the result of a multiple logistic regression analysis performed to adjust for potential confounding. In the following, the major ergonomic factors identified to be associated with musculoskeletal problems are discussed with the ultimate goal of developing guidelines for weaving workstation design to improve working posture and to reduce postural stress.

4.3.1. Loom type

As shown in Table 2, prevalence rates of symptoms in the neck, back, wrists, knees, thighs and legs were statistically higher among horizontal loom users. Multiple logistic regression analyses (Table 6) also confirmed that after adjusting for potential confounders, loom type was still one of the most significant factors for symptoms of almost all regions of the musculoskeletal system with an odds ratio (OR) of about 2. This means that weavers working at horizontal looms tend to be twice as likely to suffer from musculoskeletal problems. This can be due to severely awkward working postures adapted by weavers such that the neck and back are bent considerably and the knees are completely folded (Figure 2). Chi-square test showed significant differences between posture scores of the users of the two loom types ($p < .0001$).

4.3.2. Working posture

Here, working posture stands for postures of the neck, trunk and legs of weavers while working. Prevalence rates of symptoms in different body regions were statistically higher among those adopting non-neutral working postures ($p < .05$). Associations emerged between working posture and occurrence of musculoskeletal problems in the neck, shoulders, upper back, lower back, thighs, knees and legs (Table 6). OR ranged from 1.39 to 2.5 indicating a significant influence of the working posture on the occurrence of symptoms. In his study, Kavoussi [17] showed that non-ergonomic working posture at traditional looms reduced weavers' productivity. In addition, many studies have found positive association between deviant working postures and musculoskeletal signs and symptoms [18, 19, 20, 21, 22, 23]. Lack of workstation adjustability in a weaving operation can be the main cause of constrained, awkward postures, as it is in the case of visual terminal display (VDT) [24] and sewing operations [25]. Although in vertical looms the weaving height is a determinant factor for neck, back, shoulder and arms postures, no attention has been paid to easy adjustability of this height. In addition, seats are not adjustable in height and are located at a fixed distance from the loom.

4.3.3. Daily working time

Daily working time in the carpet industry is not usually fixed: it varies depending on the situation and workload. Motivation towards earning more money causes weavers to work longer. Because of no scheduled working time, weavers usually work continuously for a long time without a rest pause. This causes prolonged exposure to MSDs risk factors and an increased risk of disorders. In the study population, 30.5% of weavers worked longer than 8 hrs/day and 11.3% worked 11 hrs/day or more. The result revealed that daily working time had a positive association with musculoskeletal symptoms. As Table 6 shows, daily working time is a significant factor for musculoskeletal symptoms of all body regions of weavers (OR: 1.31–2). The results are in agreement with the results of Wearsted and Westgaard's study [26] in which long daily working hours were shown to be a risk factor in the development of musculoskeletal complaints among swing machine operators with OR of 1.43 for musculoskeletal disorders of all body regions.

4.3.4. Type of knots

There was an association between the type of knots and occurrence of musculoskeletal problems in shoulders and elbows. The prevalence of symptoms in those regions was significantly higher among those who used Turkish knots in their weaving as compared to those who used the Persian style (for shoulders $p = .004$ and for elbows $p = .09$). Multiple logistic regression analyses also confirmed the result (OR ≈ 1.6).

4.3.5. Type of seat

As shown in Table 4, only 8.3% of weavers using vertical loom had an appropriate seat (a chair or a bench) in their workstations and 91.7% of them sat on the ground or on a piece of lumber while working (Figure 1). It is to be noted that horizontal loom users sit on their looms as a horizontal surface in a cross-legged, squatting or folded knees posture while working (Figure 2). A Chi-square test indicated that there was an association between seat type and the occurrence of neck, shoulder, upper back, lower back, thighs and knees symptoms such that musculoskeletal problems in those regions occurred in a higher rates among those who sat on the ground or on a piece of lumber while working ($p < .05$). However, multiple logistic regression analyses demonstrated that seat type was a significant factor retained in the models for musculoskeletal symptoms of the neck, shoulders, upper back, lower back and thighs with OR ranging from 1.71 to 3.09 (Table 6).

4.3.6. Leg position

Among the weavers studied, only 25.6% worked with well-supported legs. In 74.4% of cases, legs were dangling or weavers worked in a cross-legged posture (Table 4). An awkward leg posture could be a reason for injury, swelling, and pain in weavers' lower extremities. Statistical analyses demonstrated that musculoskeletal symptoms in thighs, knees and legs were significantly more prevalent among those who worked in those non-neutral or dangling leg postures as compared to those with well-supported legs ($p < .05$). In addition, insufficient legroom causes weavers to be in a constrained position without the possibility to move and results in posture fixation. Posture fixation causes the worker not to be able to vary posture and reduce fatigue and can be very uncomfortable and fatiguing [27, 28].

It is worth noting that statistical analyses showed age, gender, marital status and job tenure to be significant individual factors associated with musculoskeletal symptoms among weavers (Table 6). However, in this study only ergonomic factors were the subject of discussion and focus for an improvement in working conditions.

4.4. Reliability Tests

The results of reliability test revealed that for almost all subjective variables the Spearman correlation coefficient were greater than .65, which could be considered acceptable for this kind of variables. McNemar and Wilcoxon tests also showed no significant difference between responses for the two occasions. The Pearson correlation coefficient for quantitative variables were greater than .9 indicating acceptable reliability of the questionnaire administration.

4.5. Workstation Design Guidelines

Based on the results of the present study, the following recommendations were developed as general ergonomic guidelines for weaving workstation design. They are oriented towards eliminating constrained, awkward postures and improving working conditions.

1. Looms should be vertical.
2. Loom height should be adjustable to permit a neutral working posture of different body parts.
3. Weaving height should be adjustable to improve neck, back, shoulder and arm working postures.

TABLE 6. Models Indicating Factors With the Strongest Influence on Musculoskeletal Symptoms in Different Body Regions of Weavers

	Factors Retained in the Model							
Body Region	**Ergonomic Factors**	**OR**	**95% CI**	***p***	**Individual Factors**	**OR**	**95% CI**	***p***
Neck	Loom type	1.98	1.43–2.74	<.0001	Age	2.22	1.73–2.74	<.0001
	Neck posture	1.79	1.25–2.54	.0020	Gender	3.38	1.13–10.14	.0300
	Daily working time	1.48	1.15–1.91	.0030				
	Seat type	1.95	1.14–3.32	.0140				
Shoulders	Seat type	2.98	1.81–4.91	<.0001	Job tenure	1.69	1.31–2.18	<.0001
	Type of knots	1.65	1.25–2.19	<.0001	Marital status	1.37	1.04–1.80	.0240
	Trunk posture	1.67	1.19–2.35	.0030				
	Daily working time	1.37	1.08–1.74	.0090				
Elbows	Daily working time	1.67	1.49–2.95	.0010	Age	2.10	1.49–2.95	<.0001
	Type of knots	1.61	1.15–2.26	.0060	Job tenure	1.64	1.16–2.31	.0050
Wrists	Daily working time	1.48	1.15–1.89	.0020	Age	1.53	1.15–2.04	.0040
	Loom type	1.54	1.12–2.12	.0080	Gender	3.58	1.34–9.60	.0110
					Job tenure	1.41	1.08–1.84	.0130
Upper back	Loom type	2.10	1.93–3.91	<.0001	Age	1.65	1.29–2.11	<.0001
	Trunk posture	2.50	1.16–2.74	<.0001				
	Daily working time	1.73	1.35–2.22	<.0001				
	Seat type	1.75	1.03–2.96	.0380				
Lower back	Loom type	2.75	1.93–3.91	<.0001	Job tenure	1.50	1.12–2.00	.0060
	Trunk posture	1.65	1.16–2.33	.0050	Marital status	1.90	1.41–2.55	<.0001
	Seat type	1.71	1.06–2.77	.0270	Age	1.41	1.05–1.86	.0220
	Daily working time	1.31	1.01–1.68	.0380				
Thighs	Loom type	2.06	1.39–3.04	<.0001	Age	1.75	1.18–2.60	.0050
	Daily working time	2.00	1.44–2.79	<.0001	Job tenure	1.63	1.11–2.39	.0130
	Leg posture	1.77	1.22–2.57	.0020				
	Seat type	3.09	1.21–7.86	.0180				
Knees	Leg posture	1.45	1.12–1.88	.0050	Age	2.50	1.90–3.29	<.0001
	Daily working time	1.35	1.04–1.76	.0260	Marital status	1.57	1.17–2.11	.0030
	Loom type	1.51	1.06–2.14	.0210				
Legs	Loom type	2.49	1.73–3.59	<.0001	Age	2.40	1.71–3.38	<.0001
	Daily working time	1.86	1.38–2.50	<.0001	Job tenure	1.87	1.33–2.62	<.0001
	Leg posture	1.39	1.03–1.88	.0340				

Notes. OR—odds ratio, CI—confidence interval.

4. A weaving workstation should be equipped with an appropriate seat (a chair or a bench). Seat height should be adjustable to accommodate both small and large weavers.
5. There must be sufficient clearance for leg movement under the loom to accommodate both small and large weavers.
6. The controls for adjusting the physical dimensions of the workstation should be easy to handle.

4.6. Application of the Guidelines and Its Evaluation in a Prototype Workstation

With regards to the developed guidelines and after a thorough study on the looms currently being used in weaving workshops, a loom and a weaving workstation prototype were designed and constructed (Figure 3). The most important feature of the workstation is its adjustability. The loom is vertical. The height of the loom and the seat is adjustable so that weavers can adjust weaving height (work level) according to their preferences.

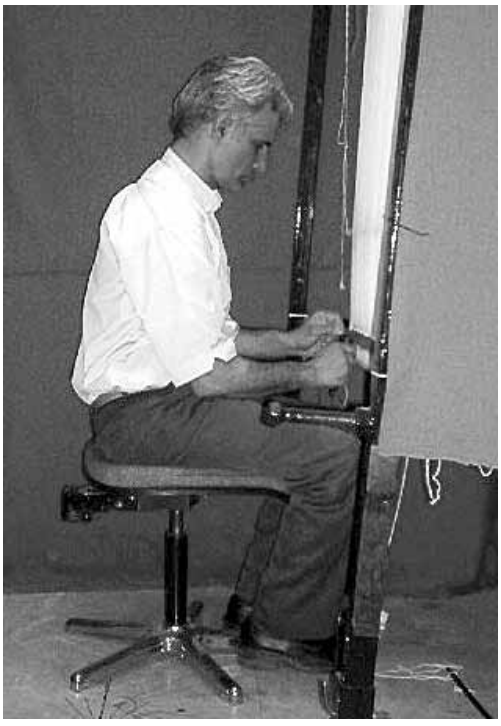


Figure 3. A prototype of the designed loom and workstation. Legs are well supported. There is enough clearance under the loom for legs. The overall body posture is neutral.

An experimental test was conducted in the laboratory to assess weavers' perception about the new workstation and working posture. Thirty experienced weavers (15 male and 15 female, mean age 29.5 years, *SD* = 7.6; mean weight 64.9 kg, *SD* = 9.6; mean stature 166.3 cm, *SD* = 8.5; mean job tenure 12.5 years, *SD* = 9) participated in this test. Each test subject performed his/her normal weaving task in a trial of 45 min. Upon completion of the trial, weavers' perception about the new workstation and working posture was investigated with a questionnaire containing two modules (scaling techniques). For assessing the new workstation, the weaver was asked firstly to assess the seat on a 4-point scale ranging from *very appropriate* to *very inappropriate* and, secondly, to compare the new workstation to his/her old workstation in the industry on a 5-point scale ranging from *much better* to *much worse*. For perceived posture investigation, the weaver was asked to rate his/her perception of the posture of the neck, back, shoulders, elbows, thighs and knees on a 7-point scale, ranging from *very favourable* to *very unfavourable*.

The results showed that 70% of the test subjects found the seat *appropriate* and *very appropriate* and comfortable during work. Fifty percent of the weavers assessed the new workstation as *better* and *much better* and 17% of them indicated that the new workstation was similar as compared to the old workstation. Most weavers perceived the posture of almost all body regions (particularly the thighs and knees) *favourable* and *very favourable* while working at the new workstation.

5. CONCLUSION

In industrially developing countries, great efforts are directed towards encouraging the development of small-scale industries as the engine for growth of their economics [6]. If the carpet industry is to work as a powerful engine to bring fruitful economic outcome, it should

receive appropriate attention from different viewpoints, above all ergonomics.

The present study showed that there was a high rate of poor working conditions and musculoskeletal problems in the Iranian hand-woven carpet industry. Thus, improvement of working conditions and control of musculoskeletal disorders risk factors seem essential. Several factors relating to the ergonomic conditions were found to be important in relation to musculoskeletal problems, especially loom type, working posture, daily working time and seat type. Musculoskeletal symptoms were also associated with individual factors including age, gender, marital status and job tenure.

The majority of ergonomic shortcomings and important factors for musculoskeletal symptoms in weaving operations originated from ill-designed weaving workstations. It can, therefore, be concluded that any working conditions improvement program in this industry has to focus on designing ergonomic-oriented weaving workstations.

The new weaving workstation based on the developed design guidelines was generally acceptable to the weavers and contributed to an improved working posture. The results of the prototype test demonstrated that the new design improved working conditions and, consequently, might reduce prevalence of MSDs symptoms. Although working posture and workstation adjustability have been considerably improved in this prototype, further work is needed to develop quantitative guidelines for optimizing the working posture.

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