Health Promotion Perspectives, 2014, 4(2), 144-150
doi: 10.5681/hpp.2014.019
http://journals.tbzmed.ac.ir/HPP

The Impact of Ergonomically Designed Workstations on Shoulder EMG Activity during Carpet Weaving

Majid Motamedzade [1], *Davood Afshari [2], Alireza Soltanian [3]

[1] *Ergonomics Department, Research Center for Health Sciences, Hamadan University of Medical Sciences, Hamadan, Iran*
[2] *Department of Occupational Health, Jundishapur University of Medical Sciences, Ahvaz, Iran*
[3] *Department of Biostatistics and Epidemiology, Research Institute of Behavioral Disorder and Substance Abuse, Hamadan University of Medical Sciences, Iran*

ARTICLE INFO

Article type:
Original Article

Article history:
Received: Feb 27 2014
Accepted: Aug 02 2014
e-published: Dec 30 2014

Keywords:
Workload,
EMG Surface,
Musculoskeletal disorders,
Workstation

***Corresponding Author:**
Davood Afshari
Tel: +98 916 616 6780;
e-mail:davodafi@yahoo.com

ABSTRACT

Background: The present study aimed to evaluate the biomechanical exposure to the trapezius muscle activity in female weavers for a prolonged period in the workstation A (suggested by previous studies) and workstation B (proposed by the present study).
Methods: Electromyography data were collected from nine females during four hours for each ergonomically designed workstation at the Ergonomics Laboratory, Hamadan, Iran. The design criteria for ergonomically designed workstations were: 1) weaving height (20 and 3 cm above elbow height for workstations A and B, respectively), and 2) seat type (10° and 0° forward-sloping seat for workstations A and B, respectively).
Results: The amplitude probability distribution function (APDF) analysis showed that the left and right upper trapezius muscle activity was almost similar at each workstation. Trapezius muscle activity in the workstation A was significantly greater than workstations B ($P<0.001$).
Conclusion: In general, use of workstation B leads to significantly reduced muscle activity levels in the upper trapezius as compared to workstation A in weavers. Despite the positive impact of workstation B in reducing trapezius muscle activity, it seems that constrained postures of the upper arm during weaving may be associated with musculoskeletal symptoms.

Citation: Motamedzade M, Afshari D, Soltanian AR. The Impact of Ergonomically Designed Workstations on Shoulder EMG Activity during Carpet Weaving. Health Promot Perspect 2014; 4(2): 144-150

Introduction

Work-related musculoskeletal disorders (WMSDs) are common among carpet weavers, especially in shoulder region that results in reduced job performance, productivity and increased time off work.[1,2] More than 2.5 million full-time workers and about 8 million part-time workers supply their living expenses through carpet weaving in Iran and women form the majority of the carpet weaving population.[3]

Weavers are exposed to many of the recognized risk factors for musculoskeletal disorders of the shoulder, including repetitive tasks, lack of work–rest regime, long duration awkward arm stooped postures, and awkward shoulder postures/motions.[4,5]

Carpet weaving demands high precision and is often performed with arms elevated and unsupported and trunk flexed forward. In general, the occupations in which the incidence of shoulder and neck symptoms is frequent, demand high precision with a high rate of repetition, and requiring the elevation of the arms for long periods.[6,7] Prolonged static contractions are a significant factor in the development of work-related muscle fatigue and symptoms.[8]

In a survey of 1439 weavers in the Iranian hand-woven carpet industry, Choobineh et al.[2] found that there was a significant difference between back pain prevalence among Iranian general population and carpet weavers and the most common musculoskeletal symptoms affected regions among the weavers were shoulder (47.8%) and low back (45.2%).

Motamedzade and Moghimbeigi[5] believe that poor workstation design, in particular, design that is inappropriate for the anthropometric dimensions of weavers, is a major risk factor for the development of musculoskeletal symptoms in carpet weaving. Epidemiological studies have shown an association between poor working postures and shoulder disorders among carpet weavers.[2,5]

It is believed that the recommended guidelines for adjustable workstations lead to improved work postures reduced muscular activation, supplied rest for musculoskeletal system, and ultimately lead to the prevention of musculoskeletal disorders.[5]

According to Choobineh al.,[2] the implementation of ergonomic interventions and the redesigning a workstation for weavers, caused that 57% of the people to report working at the ergonomically designed workstation was better than traditional workstation. Motamedzade et al.[9] proposed ergonomically redesigned hand tools for weavers. This study was conducted to investigate the design of carpet weaving hand tools. Based on the results of the field study, three prototypes of the hand tools were made. The new ergonomically designed weaving hand tools were found to be applicable and acceptable by the carpet weavers.Mostcarpet weaversare working currently at traditionalstations where they are weaving carpets while sitting cross-legged with back flexed forward for long times (over 8 hours). The height of weaving site is variable because the carpet loom is nonadjustable, so that theworkersare forcedto lower the height of loom after a fewrowsbecause of the increasedheightofweaving site. They do this manually to decrease the pressure exerted on their hands. To this end, carpet weavers require exertion of a lot offorce and taking poor postures.

The earlier studies showed that the guideline proposed for designing carpet weaver's workstation, upper arm elevation (23º) was high for both hands in spite of reducing trunk flexion.[2] These conditions may increase pressure on shoulders' muscles. Most carpet weavers had complaints of the shoulders.[2,5] Therefore, it is necessary to mainly focus on shoulders area while designing carpet weaver's workstation. Meanwhile, trunk flexion should be at a reasonable level. Accordingly, the present study aimed to evaluate the biomechanical exposure to the trapezius muscle activity in female weavers for a prolonged period in the workstation A (suggested by previous studies) and workstation B (proposed by the present study).

Materials and Methods

Participants

This study was a cross-sectional research conducted from February to September 2013 at the Ergonomics Laboratory, Hamadan University of Medical Sciences, Hamadan, Iran.Nine females participated. Table 1 shows the characteristics of the participants. None of the weavers reported any musculoskeletal disorders. All participants were right-hand dominant.

Ethical considerations

After meeting criteria, the study was explained and weavers were asked to sign an informed consent and the study protocol was approved by the Hamadan University of Medical Sciences Ethics Committee.

Experimental design

Based on Iran Environmental & Occupational Health Center recommendations,[10] the level of work environment lighting was determined as 275lux and the ambient temperature as 20-23°C.

Table 1: Characteristics of the female carpet weavers (N=9)

Variables	Mean (SD)
Age (yr)	29(5.1)
Height (cm)	160(4.9)
Weight (kg)	57.5(9.6)
Work experience (yr)	5.77 (4)

SD: Standard Deviation

Environmental conditions (lighting and ambient temperature) were identical for all two workstations.

The evaluations were done in two consecutive days. Carpet weavers were working randomly at workstationson twoconsecutive daysfor 4 hours. Assome ofthem were asked to work the first dayat the station A,and some otherswere askedto work the first dayat the stationB.Environmental conditions (lighting, ambient temperature) were identical for all two workstations. Based on the daily work schedule in carpet weaving workshops, weavers had a 20 min break after a 2 hours weaving. The ergonomically designed workstations were used in a random sequence. When carpet weavers were equipped with measurement equipment and the calibration process was done, they were asked to start weaving in usual fashion.

Workstations

The weaving equipment used was a common loom with dimensions of 1.5×2.5m.

The design criteria for ergonomically designed workstations (A and B) were: 1) weaving height (height of the location of knotting) from elbow height, and 2) seat type. Workstation A was designed based on the Choobineh et al. recommendation.[2] The seat height was 15 cm above the popliteal height and the seat had a forward slope of 10° and weaving height was 20 cm above elbow height (Fig. 1).

It seems that workstation A may increase muscular load on the upper limb muscles, so workstation B was designed based on the research team opinions and also carpet weavers' participation.[11]

Fig. 1: Workstation A representing ergonomically desingned carpet weaving based on previous studies(weaving height was 20 cm above elbow height and10° forward-sloping seat)

For each weaver, the optimum height was adjusted with due attention to the popliteal height since for best results, the seat height is recommended to be close to the popliteal height.[12] Moreover, sufficient space was provided under the carpet loom for the weavers to extend their legs comfortably the seat height designed adjustable and the seat had no forward slope. Weaving height was considered 3 cm above elbow height based on recommended dimensions in workstation design[13] (Fig. 2). In order to adjust the weaving height 3 cm above the elbow height, a weaving loom with height adjustment capability was designed. Therefore, upon the adjustment of the seat at the popliteal height for each weaver, the weaving height was set at a distance of 3 cm above the elbow height by adjusting the loom height.

Study equipment

Long-term surface electromyograms (EMGs) recordings are common in occupational studies, often recording from upper trapezius or upper extremity muscles.[14]

Two EMG electrodes with 20 mm intra-distance bipolar surface electrodes (SX230, Biometrics Ltd., UK; gain: 1000; band-pass: 20–450 Hz; input impedance $>10^{12}$ **Ω**) were placed over the right and left upper trapezius of subjects to record relevant muscular activities.

Fig. 2: Workstation B representing ergonomically desingned carpet weaving based on current study(weaving height was 3 cm above elbowing height and 0° forward-sloping seat)

The electrode positions were located according to Jensenet al.[15] The ground-reference electrode was placed around the participant's left hand. Before electrodes were placed, skin was cleaned with alcohol and hair removed with a shaver.

The electrodes were connected to a data logger and the EMG signals digitized at 1000 Hz and recorded on a compact flash memory card for further analyses. The recorded data were downloaded to a personal computer for analysis using custom programs developed in Matlab R2007B (The Math Works Inc., Natick, MA, USA). Power noise was removed with a 50 Hz, notch filter. Then the signals were filtered with a 10-400 Hz, band pass, 6thorder, zero-lagButterworth filter. The root mean square (RMS) of the signal was calculated over consecutive time windows of 125 m.

Muscle activity of right and left upper trapezius was normalized using sub-maximal reference contractions and expressed as % sub-maximal reference voluntary contractions (%RVC). The participants performed three 15-s contractions with arms abducted at 90º and with arms parallel to the ground, while holding a 1 kg weight in each hand.[16] The average of the RMS EMG signals from the three reference contractions was used to normalize the EMG signal. The signals collected during weaving activities were normalized with regard to the corresponding sub-maximal RVC for each muscle.

The amplitude probability distribution function (APDF)[17] was used to calculate peak (90th percentile), median (50th percentile), and static (10th percentile) EMG levels for each normalized RMS EMG signals.

Statistical analysis

All statistical analyses were performed using SPSS 16.0 (SPSS Inc., Chicago, IL, USA) at 0.05 level.

The Kolmogorov-Smirnov test was used to examine the normality of the distribution of data and the Shapiro-Wilk test was used for further confirmation. All data were tested to be normally distributed in each of the workstations, so the Paired *t*-tests (two-tailed) were used for data analysis.

Results

Table 2 shows APDF values for right and left trapezius muscles. APDF analysis showed that the left and right upper trapezius muscle activity was almost similar at each workstation. At workstation A, the median RMS activity was 5.7 RVE% and 5.8 RVE% for left and right upper trapezius muscles, respectively.

APDF analysis of the right and left trapezius muscle showed significantly greater 10th APDF ($P<0.01$), 50th APDF ($P<0.05$) and 90th APDF ($P<0.01$) muscle activation with use of the workstation A as compared to the workstation B.

Muscle activity of the right and left trapezius muscles were significantly lower at the

10th percentile ($P<0.05$) with use of the workstation Bas compared to workstation A.

Table 2: Amplitude probability distribution function (APDF) values for right and left trapezius muscles in 9 female weavers at studied workstations (A and B)

Upper trapezius	APDF	Workstation A Mean(SD)	Workstation B Mean(SD)
Right (RVC %)	10	[aa]8(.9)	5.2(1.2)
	50	[aa,bb]24.3(2.1)	[b]19.3(2.6)
	90	[aa,bb]42(2.5)	37(2.3)
Left (RVC %)	10	[aaa]8.2(.8)	5.4(1.3)
	50	[a]24(3)	20.8(1.9)
	90	[aa]44(2.4)	37.7(3.3)

[a]$P<.05$; [aa]$P<.01$; [aaa]$P<.001$; workstation A vs. workstation B
[b]$P<.05$; [bb]$P<.01$; [bbb]$P<.001$; right vs. left side
EMG=electromyography; RVC=reference voluntary contractions

Discussion

The present study evaluated the biomechanical exposure to the trapezius muscle activity for a prolonged period in the workstation A (suggested by previous studies) and workstation B (suggested by the present study). Epidemiological studies have shown that poor working conditions for carpet weavers is the main cause of musculoskeletal problems, especially in the region of shoulder.[5] Recently, a guideline was proposed[2] based on weaving height from elbow height and seat type. The proposed guideline may increase the postural load on the shoulder muscles that has not been evaluated to date.

In the present study, trapezius muscle activity in workstation A was significantly greater than workstations B. Greater EMG amplitude represents higher tissue load and muscular fatigue.[18]

The use of the workstation B was led to a lower upper trapezius muscle activity as compared to workstations A, especially in the 10th percentile, which represents a static load. High levels of static loading suggest that the muscles rarely return to resting levels and therefore may not fully recover.

Repetitive tasks and prolonged static activities do not give the individual enough time for recovery, bringing about muscle fatigue, loss of energy, and production and accumulation of metabolic by products in the muscle which is related tomusculoskeletal disordersin the shoulderarea.On the otherhand, people with a history of repetitive activities and static contractions experienced pain, decreased muscle blood flow, and metabolic changes in thetrapeziusmuscle.[17,18]

Choobineh et al.[2] believe that increasing the weaving height from elbow height (10 cm to 20 cm) will improve the back, neck and arm posture. Mean upper arm elevation angle at workstation A was recorded 23° using the weaving posture analyzing system (WEPAS).[2] Aaras[19]suggested that upper arm elevation angle should not exceed 15° for continuous work. With the weaving height exceeding elbow height, upper arm elevation increases as well. This increases probability of imposing pressure on shoulders' muscles, especially for long-term exposures. Activity of upper limb muscles is significantly associated with the shoulder flexion angle.[20,21]

In this study, we did not provide any report on measuring angles of shoulders. However, EMG results showed that using workstation B - as compared with workstation A – tends to reduce physical workload on shoulders, especially for static conditions (APDF 10).

Afshari et al.,[11] investigated the effects of the workstation introduced in this study (workstation B) on trunk posture and loads imposed on lumbar of carpet weavers. It was concluded that the workstation B improved trunk posture and loads imposed on lumbar in weavers. Therefore, the results of the present and previous study showed that the proposed workstation could have positive effects on physical workload imposed on shoulders and back of carpet weavers.

Muscular tension in the shoulder muscles may increase due to non-postural loads such as accuracy, increased speed of work, and stress.[22, 23] Thus, it seems that the use of the workstation B and paying attention to organizational factors such as determining appropriate work and rest times can be effective in reducing physical workload in the shoulder region.

Limitations

Lack of proper lighting in the workplace is known as a risk factor in causing awkward postures and musculoskeletal disorders.[24] In the present study, carpet loom had been installed in a laboratory environment; artificial lighting conditions were constant during each working shift (210 lux).Therefore, changing lighting conditions may affect the results of subsequent studies.

The current study, vertical loom with dimensions of 1.5 × 2.5 m were used while the type and dimensions of looms used in other areas in Iran and other countries may differ. Use of horizontal looms causes more unfavorable conditions on the musculoskeletal system than vertical looms.[5]

Conclusions

The use of the workstation B significantly reduces left and right trapezius muscle activity as compared to the workstation A. Despite the positive impact of workstation B in reducing postural load on the shoulders, it seems that lack of postural variation and constrained postures of the upper arm may be one of the main risk factors in the development of fatigue and pain in the shoulder region among carpet weavers. Thus, further interventions for reducing constrained postures seem to be of most importance.

Acknowledgements

Thanks to Deputy of Research and Technology of Hamadan University of Medical Sciences for approving and funding this research work.

Competing interests

The authors declare that there is no conflict of interests.

References

1. Nazari J, Mahmoudi N, Dianat I, Graveling R. Working conditions in carpet weaving workshops and musculoskeletal complaints among workers in Tabriz-Iran. *Health Promot Perspect* 2012;2:265–273.
2. Choobineh A, Hosseini M, Lahmi M, Khani Jazani R, Shahnavaz H. Musculoskeletal problems in the iranian hand-woven carpet industry: Guidelines for workstation design. *Appl Ergon* 2007;38:617-624.
3. Sobhe K. A research in international market of iranian carpet and its export development. *Iran Hand-Woven Carpet Magazine* 10 1997;14:31–46. [In Persian].
4. Afshari D, Motamedzade M, Salehi R, Soltanian AR. Continuous assessment of back and upper arm postures by long-term inclinometry in carpet weavers. *Appl Ergon* 2014;45:278–284.
5. Motamedzade M, Moghimbeigi A. Musculoskeletal disorders among female carpet weavers in iran. *Ergonomics* 2012;55:229–236.
6. Blader S, Barck-Holst U, Danielsson S, Ferhm E, Kalpamaa M, Leijon M , et al. Neck and shoulder complaints among sewing-machine operators.A study concerning frequency, symptomatology and dysfunction. *Appl Ergon* 1991;22:251-257.
7. Jensen BR, Schibye B, Søgaard K, Simonsen EB, Sjøgaard G. Shoulder muscle load and muscle fatigue among industrial sewing-machine operators. *Eur J Appl Occup Physiol* 1993;67:467- 475.

8. Bernard B. Musculoskeletal disorders and workplace factors: A critical review of epidemiologic evidence for work-related musculoskeletal disorders of the neck, upper extremity, and low back [Internet]. NIOSH Publication;1997.DHHS (NIOSH) Publication No. 97–141. Available from: http://www.cdc.gov/niosh/docs/97-141/
9. Motamedzade M. Ergonomics in the carpet-weaving industry in Iran. In: Scott PA, editor. Ergonomics in developing regions: Needs and applications. Boca Raton: CRC Press; 2009.
10. Environmental & Occupational Health Center, Occupational exposure limit (OEL), Iran [Internet]; 2011. Available from: http://www.ier.tums.ac.ir.
11. Afshari D, Motamedzade M, Salehi R, Soltanian AR. The impact of ergonomics intervention on trunk posture and cumulative compression load among carpet weavers. Work 2013. [Epub ahead of print].
12. Pheasant S. Body space: Anthropometry, Ergonomics and Design. 2nd ed. London: Taylor & Francis; 1996.
13. Grandjean E. Fitting the task to the man: an ergonomics approach. 4th ed. London: Taylor& Francis; 1997.
14. Jensen C, Borg V, Finsen L, Hansen K, Juul-Kristensen B, Christensen H. Job demands, muscle activity and musculoskeletal symptoms in relation to work with the computer mouse. *Scand J Work Environ Health* 1998;24:418–424
15. Jensen BR, Schibye B, Søgaard K, Simonsen EB, Sjøgaard G. Shoulder muscle load and muscle fatigue among industrial sewing-machine operators. *Eur J Appl Physiol* 1993;67: 467-475.
16. Hansson GÅ, Nordander C, Asterland P, Ohlsson K, Strömberg U, Skerfving S, et al. Sensitivity of trapezius electromyography to diferences between work tasks – influence of gap definition and normalization methods. *J Electromyogr Kinesiol* 2000;10:103–115.
17. Jonsson B. Measurement and evaluation of local muscular strain in the shoulder during constrained work. *J Hum Ergol* 1982;11:73-88.
18. Basmajian JV, DeLuca CJ. Muscles alive: Their functions revealed byelectromyography. 5th ed. Baltimore: Lippincott, Williams and Wilkins; 1985.
19. Aaras A, Westgaard RH, Stranden E. Postural angles as an indication of postural load and muscular injury in occupational work situations. *Ergonomics* 1988;31:915-933.
20. Brookham RL, Wong JM, Dickerson CR. Upper limb posture and submaximal hand tasks influence shoulder muscle activity. *Int J Ind Ergonom* 2010;40:337–344.
21. Lim CM, Jung MC, Kong YK. Evaluation of upper-limb body postures based on the effects of back and shoulder flexion angles on subjective discomfort ratings, heart rates and muscle activities. *Ergonomics* 2011;54:849–857.
22. Wahlstrom J, Hagberg M, Johnson PW, Svensson J, Rempel D. Influence of time pressure and verbal provocation on physiological and psychological reactions during work with a computer mouse. *Eur J Appl Physiol* 2002;87:257–263.
23. Mclean L, Urquhart N. The influence of psychological stressors on myoelectrical signal activity in the shoulder region during a data entry task. *Work Stress* 2002;16:138–153.
24. Johanning E, Bruder R. Low back disorders and dentistry – stress factors andergonomics intervention. In: Murphy DC, editor. Ergonomics and the dental care worker. Washington, DC: American Public Health Association; 1998.