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Assessment of ergonomic risk factors among hand-made shoes workers in Tabriz, northwestern Iran

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ABSTRACT

Background: The production of hand-made shoes exposes workers to biomechanical stressors that may result in musculoskeletal disorders of the upper extremities. The purpose of this study was to assess the level of ergonomic risk factors in hand-made shoes workers.

Methods: This cross-sectional study was conducted on 218 hand-made shoes workers employed in small traditional workshops in Tabriz, northwestern Iran. The Nordic questionnaire was used to record the symptoms of musculoskeletal disorders. Revised strain index (RSI) and the ACGIH hand activity level threshold limit value (HAL-TLV) were applied to assess the risk level using videotaping and direct observation of work cycles. For data analysis, the independent t-test, Spearman correlation, and Kappa statistics were employed.

Results: The most prevalent symptom was observed in the neck of the workers (90.7-98.4%). The mean score of RSI and HAL-TLV exceeded the safe level (RSI>10 and HAL-TLV>0.78) in upper makers and shoemakers but not in the sewing operators. The mean scores of the right hands of upper makers and shoemakers were statistically different and greater than the score of the left hand. The EM (Exertions per minute Multiplier) and IM (Intensity of exertion Multiplier) were identified as the most contributing multipliers of RSI. The scores of RSI and HAL-TLV were highly correlated and classified workers with good agreement.

Conclusions: According to RSI and HAL-TLV results, the biomechanical stress in the hands of upper makers and shoemakers should be reduced. Ergonomic interventions are proposed to decrease the repetitive actions and the intensity of forces during upper making and shoemaking tasks.

KEYWORDS: *Ergonomic assessment, shoes manufacturing, repetitive movement, strain index, hand activity*

INTRODUCTION

Musculoskeletal disorders (MSDs) are common throughout the world and are regarded as major occupational injuries in both developed and developing countries. MSDs are the leading cause of disability in muscles, tendons, ligaments, joints, blood vessels, and peripheral nerves, causing pain or discomfort [1]. Work-related Musculoskeletal Disorders (WMSDs) are conditions in which "the work environment and performance of work contribute significantly to the condition and/or the condition is made worse or persists longer due to work conditions" (p.1) [2]. In the United States of America, from 1992 to 2010, WMSDs accounted for 29–35 percent of occupational injuries and illnesses requiring days away from work. In 2007, the overall cost, direct and indirect, was estimated to be $2.6 billion [3]. Workplace activities such as heavy lifting, long work-shifts, a lack of work-rest schedules,

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repetitive movements, poor postures, vibrations, extreme static hand and arm postures are known to be risk factors of WMSDs. Demographic characteristics and psychological factors are also known to be significant predictors [4,5].

Although WMSDs impact the lower extremities, they are more prevalent in the back, lumbar, and upper extremities [6]. Neck and upper limb musculoskeletal problems account for nearly two-thirds of all occupational disorders [7]. Repetitive movements are the primary cause of symptoms in the upper limb [8]. According to the US Department of Labor in 2015, 32% of all occupational injuries and illnesses resulting in lost workdays were related to musculoskeletal disorders, 2.2% to repetitive movements [9]. Workers in the footwear industry are exposed to ergonomic risk factors that contribute to an increase in upper extremity MSDs. A systematic review of upper-limb work-related musculoskeletal disorders across occupational groups found that shoe industry workers had the greatest annual incidence of Rotator cuff syndrome [7].

Due to the high prevalence of MSDs in the footwear industry, the examination of risk factors associated with MSDs is vital in this industry [10]. The manufacturing of shoes requires demanding manual work, repeated motions, and awkward postures of trunk and upper extremities [10-12]. The level of ergonomic risk factors may vary between manual and industrial manufacturing of shoes. In manual production, workers typically use inappropriate hand tools while sitting awkwardly for extended periods. Therefore, upper-limb MSDs mainly occur due to poor working postures and manual application of force required for job completion [11,13,14]. For example, Jadhav et al. reported a high prevalence of MSDs in the manufacturing of Kolhapuri footwear in India due to poor ergonomics and old-fashioned methods of work [11]. Dianat and colleagues observed that workers in the production of Giveh (an Iranian hand-sewn shoe) perform highly repetitive tasks while seated and lean forward for extended periods of time [14].

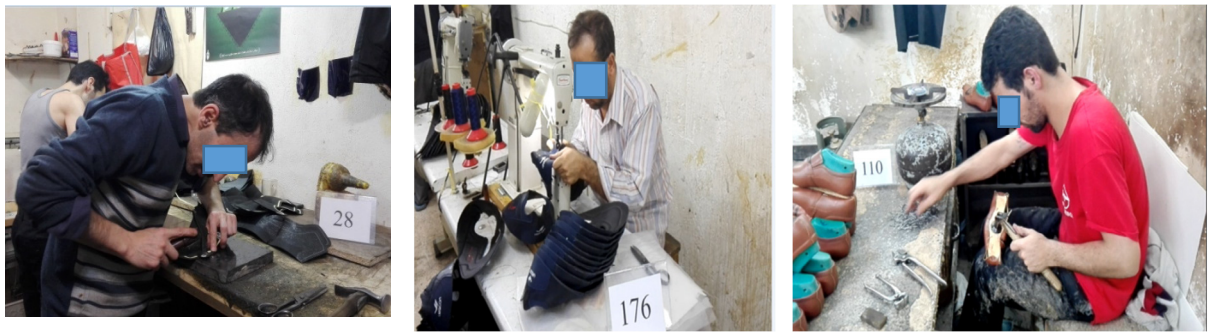
Tabriz is located in northwestern Iran and its hand-made shoes are popular due to the use of high-quality leather and its type of sewing. The shoes are registered in the list of national works. Approximately 5000 people make shoes in 1500 workshops in Tabriz. Workers usually make shoes in small self-employed workshops where they are mainly at risk of ergonomic and chemical hazards (Figure 1). The poor ergonomic work conditions are obvious as the shoe-making workers sit in uncomfortable chairs, perform tasks with awkward postures of trunk and shoulders, and sometimes on their lap, using poorly designed hand tools.

The ergonomic risk factors of workers in modern shoe manufacturing companies have been the subject of prior studies [15,16]. In these factories, tasks are accomplished with the aid of machines; consequently, the working conditions and level of ergonomic risk factors differ from shoe manufacturing by hand. On the other hand, some previous research investigated the ergonomics of hand-made shoe workers [11,14,17,18]. These studies examined the risk factors of upper limb using the Rapid Upper Limb Assessment (RULA) method in workers who made hand-woven shoes (known in Iran as Giveh) [11,14,18] and hand-sewn footwear (known in India as Kolhapuri) [17]. The majority of these workers were employed in small, home-based, and disorganized workshops. Besides RULA, many semi-quantitative observational methods, including revised strain index (RSI), ACGIH-Hand Activity Level (HAL), and occupational repetitive actions index (OCRA), are designed to quantify WMSD risk factors in workers' upper extremities [19].

To our knowledge, little is known regarding the occurrence of MSDs and ergonomic risk factors among hand-made shoe workers in Tabriz, Iran. Therefore, the current study was conducted to: (1) describe the prevalence of musculoskeletal symptoms among hand-made shoe workers, (2) assess the MSDs risk factors of hand-made shoemaking in upper extremities using RSI and ACGIH-TLV methods, and (3) compare the agreement of the risk assessment tools used.

METHODS

This cross-sectional study was conducted in hand-made shoe workshops in Tabriz, Iran. Tabriz, the 5th most populated city of the country, is located in the northwest of Iran with the coordinates of 38°4'0"N 46°17'60"E. A shoe usually consists of three main parts; upper, outsole, and insole. In order to make hand-made shoes, at first the upper of the shoes, consisting of different sections, is cut according to the desired pattern by the upper maker worker. Then the edges and thick parts are glued and hammered. Upper maker workers frequently hammer the workpiece standing up with non-neutral postures of the trunk and neck (Figure 1-A). After this step, the sewing operator sews the separate sections of the upper using special machines. Due to the need for more precision in the work, the sewing operator bends



A B C

Figure 1. Hand-sewn shoe workers: A (an upper maker), B (a sewing operator), and C (a shoemaker)

forward while sitting and working with both hands (Figure 1-B). Finally, the shoemaker attaches the upper to the insole and outsole by glue and nail using the shoe last. The shoemaker performs the task using hand tools on his lap while his body is in non-neutral postures of the trunk, leg, and neck (Figure 1-C). Hand-sewn shoe workers are exposed to ergonomic risk factors, especially in their upper extremities.

There were 1500 active shoemaking workshops in Tabriz, employing 5000 workers. Since the prevalence of musculoskeletal disorders of the upper limbs has not been documented in Iranian hand-made shoe workers, the prevalence of carpal tunnel syndrome (18.2%) was used from a similar foreign study in the shoe industry [15]. Using Cochran's formula and assuming P=0.182 (and q=0.818), a confidence level of 95%, and an error of 5%, the sample size (n) was calculated as 218 people. As a result, 218 workers were enrolled in the study through simple random sampling from workshops located in various parts of Tabriz city, including 69 upper makers, 63 sewing operators, and 86 shoemakers. Questionnaires, direct observation of workers, and videotaping of work cycles were used to collect data. After making arrangements, investigators visited each workshop to gather data. The questionnaire contained a body map with clearly identifiable body areas, such as the neck, shoulders, low back, elbows, and wrists/hands, and this was labeled so that respondents could describe the body areas of any musculoskeletal symptoms. Using the body map, respondents were asked to identify whether they had experienced any aching, pain, discomfort, or numbness in the previous year in each of the aforementioned body regions. To calculate the scores of RSI and HAL-TLV methods, working postures were analyzed using direct observation of participant postures at their workstations and videotaping of work cycles. Prior to data collection, participants were informed of the purpose and methods of the study and their satisfaction was ascertained. The ethics committee of Urmia University of Medical Sciences approved the study's ethical considerations under the code IR.UMSU.REC.1395.195.

The Revised Strain Index (RSI) and Hand Activity Level Threshold Limit (HAL-TLV) were used to assess upper limb risk factors in hand-made shoe manufacturing workers. Moore and Garg introduced the strain index (SI) in 1995 for ergonomic investigation of distal upper extremity disorders [20]. A revision of SI (RSI) was recently published by Garg and coworkers [21]. SI and RSI are conceptually the same, but RSI has three key differences with SI; removing the speed of work, considering the duration per exertion instead of the duty cycle, and using continuous variables instead of categorical multipliers. Therefore, after determining the values of the five variables of RSI, the coefficients for each variable are calculated. For example, the EM is calculated by the following formula depending on which group the efforts per minute (E) falls into:

$$EM = \begin{cases} 0.10 + 0.25.E \ , E \le 90/m \\ 0.00334.E^{1.96}, E > 90/m \end{cases}$$

Other coefficients are presented in detail in the RSI's original study [21]. Finally, the RSI value will be obtained using the following formula;

RSI=IM×EM×DM×PM×HM

Where, IM= Intensity of exertion (force) multiplier, EM=Exertions per minute (frequency) multiplier, DM= Duration per exertion multiplier, PM= Hand/wrist posture multiplier, and HM=Duration of task per day multiplier. Based on the obtained RSI value, the situation could be classified into "safe" (RSI≤10) and "hazardous" (RSI>10). In the validation of the RSI

for predicting risk of incident carpal tunnel syndrome in a prospective cohort, Kapellusch et al. discovered that higher cumulative RSI scores are associated with a higher risk of carpal tunnel syndrome (CTS). They concluded that RSI may be useful as a tool for risk surveillance and intervention design [22].

Hand Activity Level Threshold Limit (HAL-TLV) was proposed by the American Conference of Governmental Industrial Hygienists (ACGIH) to evaluate occupational risk factors leading to musculoskeletal disorders of the upper limbs in single-task jobs that are performed for at least four hours. The validity and reliability of this method has been evaluated as moderate [23,24]. HAL-TLV could be determined by a chart developed by ACGIH or using a simple formula. When using the formula, the scores >0.78 is categorized as above the TLV or dangerous, 0.56-0.78 is between AL to TLV, and <0.56 as lower than AL [25]. The prevalence of MSDs in the neck, lower-back, shoulder, elbow, and hand/wrist of workers over the past year was recorded using the Nordic musculoskeletal questionnaire [26]. The demographic information of participants was also collected by Nordic questionnaire.

The data were analyzed using version 19.0 of the Statistical Package for the Social Sciences (SPSS) (SPSS Inc., Chicago, IL, USA). The prevalence of MSDs, and the scores of RSI and HAL-TLV methods were calculated using descriptive statistics. An independent sample t-test was performed to compare the mean score of RSI and HAL-TLV between right and left hands. Kappa agreement coefficient and Spearman correlation coefficient were computed to assess the agreement between the RSI and HAL-TLV methods in classifying workers into various risk groups.

RESULTS

The study involved 218 workers; 205 (94%) were right-handed and 13 (6%) were left-handed. The mean ±SD of the age and work experience of the workers were 41.14±8.77 and 20.71±7.83, respectively.

The prevalence of musculoskeletal disorders in the neck, lower-back, and upper extremities of workers is reported in Table 1. The most prevalent symptom is related to the neck of the workers (90.7-98.4%) in the order of sewing operators> upper makers> shoe makers. It is revealed that the prevalence of symptoms in the right shoulder, elbow, and hand/wrist of the workers was higher than the left side. In each task, most of the workers reported pain in both sides of their shoulder, elbow, and hand/wrist. It demonstrates that hand-made shoes workers' right hands are more likely to be exposed to ergonomic risk factors than their left hands.

Tables 2 and 3 summarize the statistics of RSI and HAL-TLV for hand-made shoes workers. Based on the mean score of RSI and HAL-TLV, the risk level in shoemakers was greater than the upper makers and sewing operators, respectively. Except for the sewing operators, the mean score of RSI and HAL-TLV of the right hand of upper makers and both hands of shoemakers were higher than the safe level. Also, in upper makers and shoemakers, the mean scores of RSI and HAL-TLV were statistically different between both hands (P-value<0.05).

Figure 2 depicts the score of RSI components in hand-made shoes workers. As seen, the EM and IM multipliers contributed the most to the final RSI score. The EM multiplier of the right hand was greater than that of the left hand in upper makers and shoemakers, but it was about equal in sewing operators.

Table 4 shows the risk classification of workers by RSI and HAL-TLV methods. According to Table 4, the upper makers and shoemakers were categorized in hazardous and above TLV groups of RSI and HAL-TLV methods. In contrast, the sewing operators were mainly classified in the safe and below the action level of these methods.

Table 5 shows the agreement and correlation of RSI

Table 1. The prevalence of musculoskeletal symptoms in different body parts of hand-made shoes workers during the past year of study

Workers	Neck n(%)	Lower-back n(%)	Shoulder n(%)			Elbow n(%)			Hand/Wrist n(%)		
			Left side	Right side	Both side	Left side	Right side	Both side	Left side	Right side	Both side
Upper maker (n=69)	63(91.3)	44(63.8)	0	5(7.2)	49(71)	2(2.9)	11(15.9)	8(11.6)	0	55(79.7)	11(15.9)
Sewing operator (n=63)	62(984)	57(90.5)	1(1.6)	1(1.6)	48(76.2)	5(7.9)	0	29(46)	0	1(1.6)	10(15.9)
Shoemaker (n=86)	78(90.7)	67(77.9)	4(4.7)	17(19.8)	46(53.5)	2(2.3)	12(14)	24(2.9)	1(1.2)	6(7)	79(91.9)

Table 2. The score of RSI and its comparison among hand-made shoes workers

Workers	Hand	Mean (SD)	Range	Median	Inter quartile range (IQR)	T-test results	
						Mean difference	P-value
All workers (n=218)	Right	56.38(36.55)	134.8	56.82	81.29	36.34	0.001
	Left	20.03(17.76)	100.38	8.93	26.88		
Upper makers(n=69)	Right	58.27 (19.06)	125.75	53.58	14.06	50.55	0.001
	Left	7.72(8.62)	72.73	6.40	1.34		
Sewing operators (n=63)	Right	9.10(1.60)	7.69	8.79	0.41	0.71	0.80
	Left	9.03(1.57)	6.98	8.65	0.55		
Shoemakers (n=86)	Right	89.50(18.68)	113.91	91.28	15.37	51.53	0.001
	Left	37.97(14.34)	78.90	34.90	3.23		

Table 3. The score of HAL-TLV and its comparison among hand-made shoes workers

Workers	Hand	Mean (SD)	Range	Median	Inter quartile range (IQR)	T-test results	
						Mean difference	P-value
All workers (n=218)	Right	1.004(0.64)	1.64	0.83	1.53	0.54	0.001
	Left	0.64(0.38)	1.64	0.22	0.72		
Upper makers(n=69)	Right	0.81(0.09)	0.72	0.83	0.00	0.69	0.001
	Left	0.12(0.08)	0.72	0.11	0.00		
Sewing operators (n=63)	Right	0.26(0.16)	0.61	0.22	0.00	0.00	1
	Left	0.26(0.16)	0.61	0.22	0.00		
Shoemakers (n=86)	Right	1.69(0.21)	0.92	1.75	0.00	0.81	0.001
	Left	0.88(0.21)	0.92	0.83	0.00		

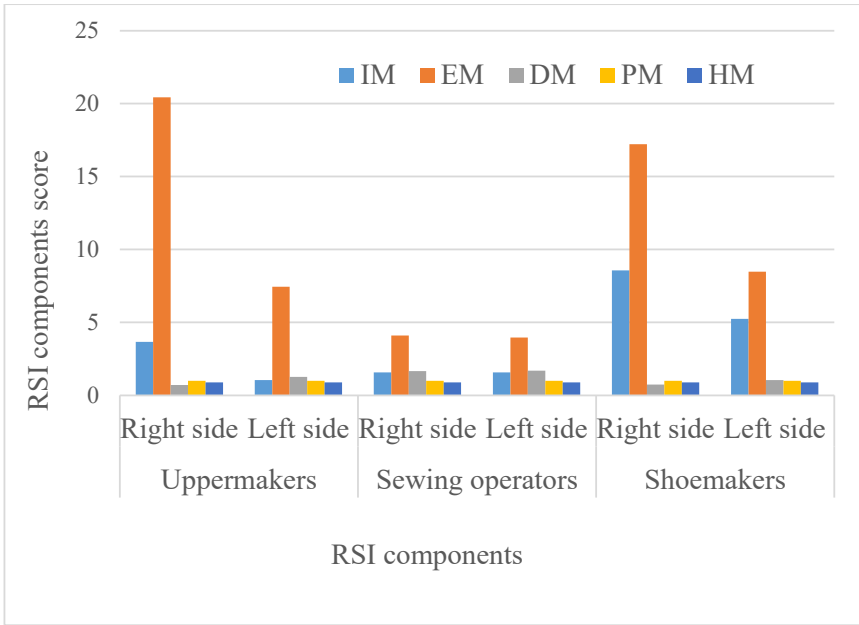


Figure 2. The score of RSI components in different tasks of hand-made shoes making (IM: Intensity of exertion multiplier, EM: Exertion per minute multiplier, DM: Duration per exertion multiplier, PM: Hand/wrist posture multiplier, and HM: Duration of task per day multiplier)

and TLV-HAL methods for the right and left sides of hand-made shoes workers. In order to check the agreement, the two levels of RST (safe and hazardous) were tested with two levels of HAL_TLV (below and above the TLV). As can be seen in Table 5, the results of the two methods have a high correlation and a good agreement in classifying workers into two hazardous and safe groups.

Table 4. Risk classification of workers by RSI and HAL-TLV methods in hand-made shoes workers

Workers	RSI		HAL-TLV		
	Safe (≤10) n(%)	hazardous (<10) n(%)	below AL (<0.56) n(%)	between AL and TLV (0.56-0.78) n(%)	above TLV (>0.78) n(%)
Upper makers(n=69)	1 (1.4)	68(98.6)	1(1.4)	3(4.3)	65(94.2)
Sewing operators	63(100)	0(0)	58(92.1)	0(0)	5(7.9)
Sewing operators (n=63)	0	86(100)	0(0)	0(0)	86(100)

Table 5. The agreement and correlation of RSI with TLV-HAL

Hand	Agreement		correlation	
	Kappa coefficient	P-value	Spearman r	P-value
Right	0.91	0.001	0.91	0.001
Left	0.92	0.001	0.89	0.001

DISCUSSION

The aim of this study was to evaluate the ergonomic risk factors of MSDs of hand-made shoes manufacturing workers in upper extremities using RSI and TLV-HAL methods. The majority of hand-made shoes workers reported the prevalence of MSDs in their neck, shoulder, elbow, and hand/wrist. Observation of work cycles by RSI and HAL_TLV revealed that the hand-made shoes workers experience biomechanical stress in their upper extremities, especially upper makers and shoemakers.

The most common MSDs symptom reported by workers in the current study was neck pain. This could be related to the visual requirements of manufacturing tasks. Neck pain was also noted as the second most prevalent symptom in traditional shoes manufacture, such as Giveh (68.9%) and Kolhapuri (97%) [11,14]. Similar to our findings, the three body regions of the neck, shoulder, and low back had the highest prevalence of musculoskeletal symptoms among hand sewing workers [27]. Similarly, the neck symptom (76%) was the most prevalent MSDs in Ethiopian sewing machine operators [28]. As a result, working conditions in shoe manufacturing and other similar industries should be improved to reduce MSD symptoms in workers' neck, shoulder, and lower back.

Similar studies in Iran and other countries such as India have investigated the working conditions of hand-sewn shoe workers. Manufacturing of Kolhapuri footwear in India is performed in a sedentary position for an extended period of time (3-4 hours in the same position). The knees of workers are folded underbody when working. All of these activities require the workers to bend forward in order to visualize the task. This necessitates the use of inadequate cross-leg postures [11]. During the manufacturing of Iranian Giveh shoes, workers perform highly repetitive tasks in a seated position over an extended length of time. Workers have to lean forward to see the point of operation and have greater visual control of the work process, leading to the adoption of poor ankle and knee postures [14]. Therefore, the higher prevalence of MSDs in the manufacturing of Indian Kolhapuri footwear and Iranian Giveh shoes were related to the awkward postures and poor ergonomics of work practices. Salve and Jadhav reported a high prevalence of wrist pain, low back pain, shoulder pain, and neck pain among female workers manufacturing Indian traditional footwear [29]. The ergonomic evaluations in industrial production of footwear in Brazilian shoe manufacturing companies also showed a higher prevalence of MSDs in the hands of workers [16]. Therefore, it can be concluded that the manufacturing of shoes poses biomechanical stress on different body parts of workers due to repetitive actions and forceful exertions.

According to the RSI method, the upper makers and shoemakers were classified in the hazardous group (>10) of this index and therefore these workers were at risk of developing MSDs in their upper extremities. This higher degree of ergonomic exposure could be related to the higher values of the EM and IM multipliers of RSI. In other words, the repetitive actions and intensive application of force during performing the tasks could increase the score of RSI. It was observed that upper makers hammer the edge of the upper part of a shoe using a hammer with intensive and repeated hammering. In shoemakers, both the duration of efforts and the intensity of force are high. Shoemakers use pliers to pull and fix the upper of shoes on the last forcefully, and then nail the upper to the last repeatedly. These working

conditions could lead to an increase in RSI score in these workers. Therefore, to reduce musculoskeletal injuries in the upper extremities of upper makers and shoemakers, ergonomic interventions should be focused on hammering activities, adjusting upper on the shoe last, and nailing activities. The results of the TLV-HAL method were similar to the RSI method. In other words, workers in shoemaking and upper making tasks were classified in the hazardous group, and sewing operators were mostly classified in the safe exposure group with a score of less than 0.56.

As one of the objectives of the study, the results of RSI and TLV-HAL methods were compared. Kappa coefficient was used to check the agreement of the two methods in the classification of exposures and Spearman's correlation coefficient was used to check the correlation of the scores obtained. Based on the results of Table 5, it can be said that the score of RSI and HAL-TLV were highly correlated and well agreed in classification of workers in risk groups. It should be noted that the reason for this high agreement is the higher correlation between EM multiplier (in RSI method) and HAL (in HAL-TLV method) as well as between IM multiplier (in RSI method) and NPF (in HAL-TLV method). In other words, the results of the RSI method were more affected by the values of the EM and IM multiplier, and the DM, PM, and HM multiplier did not have such an effect on the RSI score. Therefore, the high correlation and agreement between RSI and HAL-TLV may be limited to this study and its generalization to other workers should be done with caution. In previous studies, the agreement and correlation of SI and HAL-TLV methods have been investigated. For example, it was determined that Spearman's correlation coefficient between TLV-HAL and SI for the right and left hand was 0.73 and 0.78, respectively, and the kappa coefficient of the two methods for the right and left hand was 0.45 and 0.051, respectively [30].

Besides the physical environment of the workplace, psycho-social risk factors could contribute to the occurrence of MSDs symptoms. Based on the field observations of the current study, the workers expressed their job dissatisfaction due to the lack of job security and low income. These psycho-social factors can help in the development of MSDs in shoe manufacturing workers. In a shoe industry in Brazil, a significant relationship was found between some psycho-social factors such as stress and the report of MSDs symptoms in the knee and elbow of workers [31].

In addition to biomechanical stress, hand-made shoe workers are also exposed to hazardous substances such as chemical vapors [32,33]. Eye problems were also among the complaints of the participants in this study. Regular work-rest cycles have beneficial effects on eye strain in footwear manufacturing facilities [34]. Industrial hygiene controls, such as general and local ventilation, as well as worker training on MSDs and chemical hazards, could protect shoemakers from occupational hazards [35,36].

This study had some limitations. This investigation was an observational and cross-sectional study. The authors did not perform electro diagnostic tests such as nerve conduction to objectively diagnosis MSDs such as carpal tunnel syndrome. With such data and an examination of the relationship between observed biomechanical stresses and objective data, the validity of the results, particularly the RSI method, could be determined. Therefore, it is proposed to conduct longitudinal studies recording ergonomic exposures and upper extremity morbidities simultaneously in shoemakers. Roquelaure et al. used this method in a modern shoe factory with the participation of 253 workers for the purpose of active surveillance of musculoskeletal disorders [15]. They believe that in order to predict the risk of musculoskeletal disorders, risk factors and health outcomes should be monitored simultaneously.

CONCLUSION

The findings of this study showed that the prevalence of MSDs in hand-made shoe workers was high. Based on the RSI and HAL-TLV methods, the workers were at risk of developing MSDs in their upper extremities, especially in the upper making and shoe making tasks. Preventive measures and ergonomic interventions should be guided to decrease the score of EM and IM multipliers in hand-made shoe manufacturing. Automated equipment in shoe manufacturing could reduce overexertion and repetitive motions, which could result in a lower risk level. Due to the improvements made in the SI method and the presentation of the RSI method, it is recommended to conduct similar studies in industries where upper extremity musculoskeletal disorders are prevalent.

COMPETING INTERESTS

The authors declare that they have no competing interests.

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