Research Article

The Assessment of Occupational Ergonomic Risks of Handloom Weaving in Northern Thailand

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Abstract

The aim of this work was to compare occupational ergonomic risks of three types of handloom weaving in northern Thailand, namely traditional weaving, Kikratook weaving and Teen Chok weaving. One hundred and five weavers were interviewed and ergonomic aspects of each type of weaving were assessed by observation of work practices and the use of a number of established ergonomic risk assessment tools; RULA, ACGIH-HAL, SI. The prevalence of symptoms or likelihood of risk, as a function of handedness and weaving type was assessed. One way ANOVA was used to investigate between-group means.

The highest frequency of reported pain was in the back, neck and shoulder. The highest frequency of exertion was found in Kikratook weaving. The average final RULA score was found to be 6.80$\pm$ 0.41 points. The results of the highest risk HAL-NPF ratio score and SI score of the hand were found in the left hand with the Kikratook weaving and the right hand with the Teen Chok weaving. The average SI score in the Kikratook weaving had maximum score of the left hand. The ergonomic risk assessments by all three methods were likely to give similar results, except RULA which was unable to analyze the difference of individual weaving. SI is more difficult and complex than the ACGIH-HAL and RULA. The assessment of occupational ergonomic risks using three screening tools was consistent with reported symptoms. The risk of hand weaving was found to be pain caused as a result of work. Attention should therefore be given to the improvement of workstation and tool design in home weaving with special consideration of the anthropometric profile of the user group.

Keywords: Occupational Ergonomics; Risk Assessment; Handloom Weaving

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1. Introduction

Many women in rural locations throughout Asia are engaged in home-based weaving. This work offers flexible working hours and the opportunity to combine an earning opportunity with their domestic responsibilities [1]. Several studies have reported a range of work-related musculoskeletal disorders (WMSDs) among home-based weavers. The most frequently reported symptoms are back, neck, and shoulder pain. Large numbers of weavers are found in rural parts of northern Thailand, the poorest part of the country, and are heavily dependent on the income generated by weaving. This is therefore an important public health issue [2,3].

Several validated screening tools have been developed for the assessment of musculoskeletal risk in working populations. Available tools can be classified as designed for either subjective or objective assessment. The simplest forms of subjective assessment are unstructured observation or worker self-assessment. More structured forms of subjective assessment entail observation and recording of key ergonomic variables. These methods entail the use of checklists or questionnaires. Due to the relative ease of use of subjective methods they are often preferred to objective methods which are more complex and require the use of scientific instrumentation [4]. A study of three subjective ergonomic assessment methods, the Ovako Working Posture Analysis System (OWAS), Rapid Upper Limb Assessment (RULA) and the Strain Index (SI), found good agreement between them [5].

Available subjective assessment methods utilize multiple measures of ergonomic stress to investigate WMSDs at different points in the upper body. Several methods may therefore be used in conjunction in a complementary or corroborative manner in ergonomic investigations.

Since handloom weaving involves a variety of muscle use patterns, the selection of only one method may not be sufficient for the ergonomic risk assessment. In this study, upper body ergonomic risk was assessed using RULA[6], hand activity was evaluated using the ACGIH Hand Activity Level (ACGIH-HAL), and the workload was assessed using the SI.

The Strain Index (SI) was proposed by Moore and Garg [7] as a means to assess WMSDs of the distal upper extremities (hand, wrist, and elbow). The SI is a semi-quantitative method that estimates risk on the basis of six variables including the intensity, duration and frequency of exertion, hand/wrist posture, speed of work and daily duration of task performance [8].

The ACGIH-HAL offered the evaluation of risk factors associated with the weaver's hand and wrist disorders. The evaluation was based on the assessment of hand activity and the level of effort for a typical posture while performing a short cycle task in handloom weaving. The ACGIH-HAL considered two factors; Hand Activity Level (HAL) and Normalized Peak Force (NPF) to assess risk level. The HAL evaluated quantity using work study method, and quality using direct observation method [9]. The NPF was evaluated using the self-report body discomfort rating chart based on Borg's 10 point rating scales [10].

HAL and NPF are combined on a graph showing Threshold Limit Value (TLV) and the Action Limit (AL). The TLV and AL demonstrated the risk at the 0.78 and 0.56 points of the ratio between NPF and HAL (Ratio = NPF/ (10-HAL)). If the score of the ratio is greater than the TLV, it indicates that hand activities were at risk and control should be employed. If the score of the ratio is greater than the AL, but not exceeding the TLV, it indicates that the activity should consider risk control measures and risk monitoring. Moreover, a score below the AL indicates that nearly all workers may be repeatedly exposed without adverse health effects.

The present study was initiated to apply the techniques described above to investigate WMSDs in three types of handloom weaving; namely traditional, Kikratook and Teen Chok weaving.

2. Materials and Methods

2.1 Study Design

The study employed a cross-sectional design. Data collection was conducted from October 2012 to February 2013.

2.2 Study Population and Sample

The study was conducted in northern Thailand where several clusters of weavers, including traditional, Kikratook and Teen Chok weaving, are located. Participants were professional weavers with more than one year of weaving experience. The estimated proportion of the population was computed by the number of samples at the confidence level of 95 percent. A multistage sampling design was adopted; for each of the three weaving-types, seven clusters of five individuals were identified giving a total of 105 participants. Clusters were sampled randomly.

2.3 Measurement Methods

Each participant was interviewed and observed. RULA, ACGIH-HAL and SI were selected for use due to their relevance and the complementarity of these models in the context of weaving; RULA to evaluate working posture, HAL to evaluate hand activity and exertion, and SI to evaluate both motion and force as the product of force and frequency.

Photography and video recording were performed for later viewing to review on-site findings.

2.4 Data Analysis

Descriptive statistics were used for analysis of demography, work practices and relevant variables. The One way ANOVA was used to investigate between-group means and the Scheffe test was used for post-hoc analysis. The post-hoc tests were run to confirm where the differences occurred between groups. A paired t-test was used for differences between hands. A p-value less than 0.05 was considered significant. All analysis was performed using a statistical package program.

2.5 Ethical Consideration

This study was approved by the Human Research Ethics Committee of Thammasat University (No. 060/2555).

3. Results

The mean age of subjects was 57.21$\pm$10.41 years. Weaving experience varied from one to 61 years with the average of 22.15$\pm$17.53 years. The number of working days per week ranged from 3-7 with a mean of 6.44$\pm$1.08 days/week. Daily working hours varied from 1 to 12 with a mean of 7.16$\pm$1.57 hours/day.

3.1 Assessment of Symptoms

Symptoms were assessed by participants assigning the location of pain to the body discomfort rating chart. Intensity was assessed by responses to the Borg 10 point rating scale. The frequency of pain in core regions was reported as follows: lower back (81%), upper back (65%), and neck pain (64%), and in limbs was reported as right shoulder (87%), left shoulder (83%), right knee (64%), left knee pain (59%) right hand pain (49%) and left hand pain (45%) (Figure 1).

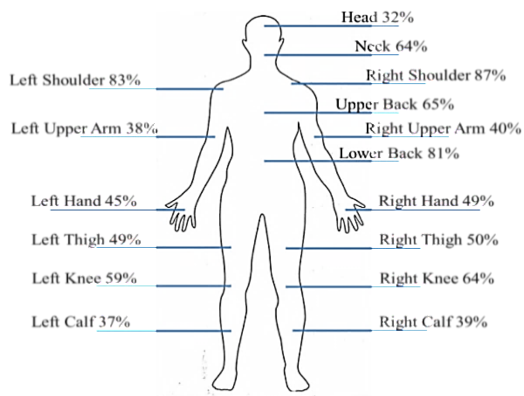


Fig.1. Subjective assessment of pain in different body parts after weaving.

3.2 Observational Assessment

Working time study was conducted through the observation of all weaving periods in order to measure activities and frequency of hand exertion in a cycle working time.

The highest percentage average hand exertion was found in Kikratook weaving, followed by Teen Chok weaving, and traditional weaving (Table 1).

Table 1. Percentage of the averaged hand exertion and average of exertion (exertions/min) among handloom weavings in a cycle time by observation.

		$\bar{x}$ (n=105)	Traditional weaving (n=35)	Kikratook weaving (n=35)	Teen Chok weaving (n=35)	p-value
Percentage of the averaged exertion ($\bar{x}$±SD)		**69.85±25.52**	43.60±11.84	98.86±2.79	67.08±16.15	<0.001
Average of exertion (exertions/min) ($\bar{x}$±SD)	**Left hand**	**19.51±9.37**	12.70±3.53	30.38±3.77	15.44±7.41	<0.001
	Right hand	**22.29±8.85**	12.47±3.17	30.38+3.77	24.88±5.81	<0.001

For assessment of the frequency of exertion, job characteristics of traditional weaving were considered based on shuttle for weaving yarn. Kikratook weaving was considered based on jerk string and percussion beater. Teen Chok weaving was considered based on weaver fingers or needle to weave yarn. From Table 1, the highest frequency of exertion occurred in Kikratook weaving both in the left and right hands.

3.3 Upper Body Assessment with RULA

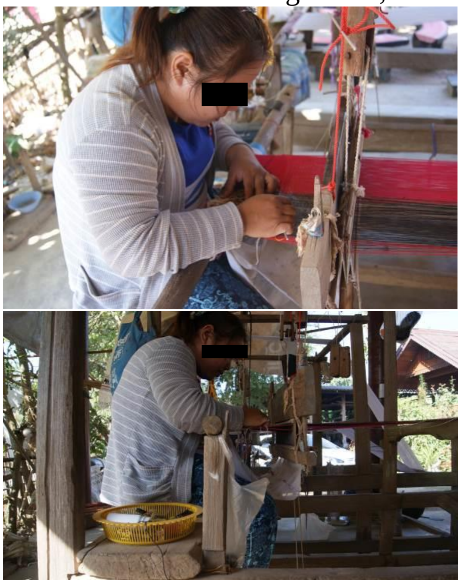
For RULA score analysis, the average score of each weaving method was equal to the average score of all three weaving methods, i.e., 6.80±0.41 points with minimum of 6 points and maximum of 7 points. However, the highest score of Upper limb occurred in Teen Chok weaving both in the left and right side. Moreover, the highest score of Upper arm occurred in Kikratook weaving in the right hands. Working postures are shown in Figure 2.

- Shoulder abduction
- Shoulder flexion > 45^o
- Raised shoulder
- Wrist flexion, bent, and twisted
- Neck flexion, twisted, and lateral bending
- Twisted trunk
- Legs/feet unsupported or balance uneven
- Repetitive motion

Figure 2A, Awkward postures of Traditional weaving

- Shoulder abducted > 90°
- Shoulder flexion > 45°
- Raised shoulder
- Wrist flexion, and twisted
- Neck flexion, twisted, and lateral bending
- Trunk flexion
- Legs/feet unsupported or balance uneven
- Arm exertion during working
- Repetitive motion

Figure 2B, Awkward postures of Kikratook weaving



- Upper arm abducted
- Shoulder flexion > 45°
- Wrist flexion, bent, and twisted
- Arms across midline or out to side of body
- Neck flexion and twisted
- Trunk flexion
- Raised shoulder
- Twisted trunk and side bending
- Legs/feet unsupported or balance uneven
- Mainly static posture

Figure 2C, Awkward posture of Teen Chok weaving

Fig.2. Awkward postures in each type of weaving.

3.4 Assessment of Hand Activity by ACGIH-HAL

Data from the use of the ACGIH-HAL method are shown in Table 2. The average ratio score for the quantitative method was 0.69 and 0.86 in left and right hands, respectively. The left hand had a higher average ratio score than the AL but did not exceed the TLV. The average ratio score of the right hand exceeded the TLV suggesting a risk of right hand injury in this group. The average ratio score for the qualitative assessment was 0.81 and 1.07 for left and right hands, respectively, indicating that mean scores for both hands exceeded the TLV (Table 2).

Table 2. Assessment of risk ratio score for hand exertion by the HAL-ACGIH method.

	Ratio score ($\bar{x}$±SD) **quantitative assessment**			**Ratio score** ($\bar{x}$±SD) **qualitative assessment**		
	Left hand	**Right hand**	**p-value**	**Left hand**	**Right hand**	**p-value**
Traditional weaving	0.56±0.25	0.59±0.21*	0.187	0.67±0.31	0.71±0.29*	0.142
Kikratook weaving	0.88±0.34**	0.93±0.36	0.106	1.10±0.40**	1.18±0.46	0.072
Teen Chok weaving	0.61±0.26	1.04±0.34*	<0.001	0.66±0.30	1.33±0.40*	<0.001
$\bar{x}$ (n=105)	**0.69±0.32**	**0.86±0.37**	<0.001	**0.81±0.40**	**1.07±0.47**	<0.001

**$p<0.05$ for weaving-type (ANOVA)
* sig (significant difference between Traditional weaving and Teen Chok weaving *($p<0.001$)*)

Ratio scores by hand differed between weaving types. Left hand activity in Kikratook weaving was significantly greater than other weaving types producing higher ratio scores in both quantitative and qualitative assessments (p<0.05). However Teen Chok weaving had higher ratio scores for the right hand than the other weaving types in both quantitative and qualitative assessments. This difference reached significance in relation to traditional weaving (p<0.001)

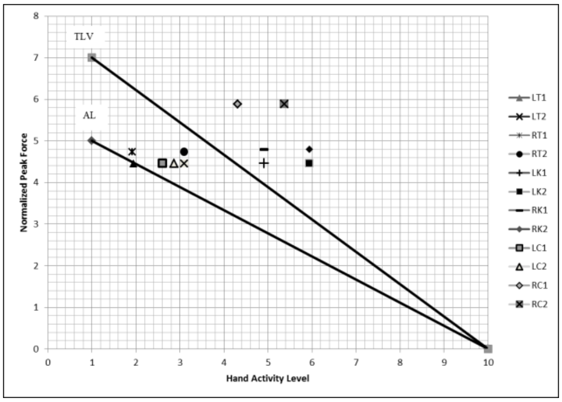


Fig.3. AL and TLV for Hand activity in handloom weaving**.**

Note :
L = Left
R = Right
T = Traditional weaving
K = Kikratook weaving
C = Teen Chok weaving
1 = Quantitative assessment
2 = Qualitative assessment

Figure 3 shows that quantified left hand activities in traditional weaving (LT1) were lower than the AL. Activities greater than AL, but not exceeding the TLV, were a) the left hand in traditional weaving from qualitative assessment (LT2) and the right hand in both assessments (RT1, RT2), and b) the left hand in Teen Chok weaving from both assessments (LC1, LC2). Activities that demonstrated scores greater than the TLV in both quantitative and qualitative assessments were left and right hands in Kikratook weaving (LK1, LK2, RK1, RK2), and the right hand in Teen Chok weaving (RC1, RC2) .

3.5 Assessment of Hand Activity with the Strain Index (SI)

The highest average Strain Index score was found in Kikratook weaving in the left hand. The analysis of variance showed that the Strain Index scores were significantly different from other weavings (p<0.001). When tested in pairs using the Scheffe test, the Strain Index scores of the left hand of Kikratook weaving were found to be greater than other types of weaving (p<0.001) (Table 3).

Table 3. SI score among handloom weavings in a cycle time**.**

	SI score ($\bar{x}\pm$SD)	
	Left hand	**Right hand**
Traditional weaving	19.95±21.63	20.80±19.52 **
Kikratook weaving	67.88±36.15 **	76.56±42.96
Teen Chok weaving	31.56±28.37	87.69±44.23
$\bar{x}$ (n=105)	**39.80±35.56**	**61.68+47.25**

** *p<0.001* for weaving-type (ANOVA)

For the right hand, Teen Chok weaving was found to have the highest SI score (*p*<0.001).When tested in pairs using the Scheffe test, the Strain Index score in the Traditional weaving was significantly less than other groups (*p*<0.001). Workload of the Strain Index scores for both left and right hands in each type of weaving had multiplied more than seven points.

4. Conclusion and Discussion

The results of this study are also in accordance with the study concerning the interviews on muscular aches and pains from silk weaving in the Isan region of Thailand [12], and in Phayao province, Northern Thailand [13]. In northeast India, a high prevalence of ergonomic risk factors related to the present handloom workstation in the weaving units was found, suggesting that ergonomic intervention is required in the present work situation [3]. The ergonomic problems stemmed from inappropriate workstation design and awkward postures. Mostly, musculoskeletal problems have been found in shoulder, waist, and upper back. The most important problem was found in awkward and static posture during operation over long periods of time.

The highest frequency of hand exertion occurred in Kikratook weaving. Kikratook weaving requires the right hand of the weaver to jerk the rope in order to send the shuttle, whereas the left hand is required to pull the beater to make yarn phased rhythms [13]. Thus, the right and left hands move in coordination while weaving. Results of the qualitative and quantitative assessments presented here indicate that the average activity of the right and left hands is very similar. The result of HAL-NPF ratio score showed that in Kikratook weaving, the left hand is involved in risk more than in other weavings. In Teen Chok weaving, the right hand activities were at the highest risk and different from traditional weaving. It may be because of the pattern of using muscles in Teen Chok weaving with twisting hand from a neutral posture.

The average RULA score of each weaving type was found equaled to the average RULA score of all weaving types: 6.80±0.41 points, with the minimum score at 6 points and the maximum at 7 points, which explains the high risk that should be carefully analyzed to improve the workstations immediately [11]. All three weaving types with awkward postures included shoulder abduction, shoulder flexion, wrist flexion; bent and twisted, neck flexion; twisted, and lateral bending, trunk twisting, and static or dynamic posture, that caused pain as a result of weaving. The average Strain Index score in Kikratook weaving had the maximum score in the left hand.

Thus, handloom weavers should be interested in improving weaving workstations and in developing tools used in weaving by considering individual weaver's posture, body size and ergonomic design.

Subsequently, musculoskeletal problems could be reduced in handloom weaving. Major causes of these musculoskeletal disorders came from poor textile workstation design [14].

Regarding discomfort, the highest number of weavers reported discomfort in the upper limb in consistent RULA scores. This high risk indicated careful analysis to improve workstations should be done immediately. Furthermore, SI scores of both left and right hands in each weaving type had weaving workload more than seven points meaning that handloom weaving is a risky job that needs work improvement. The result of the HAL-NPF ratio score indicated that the left hand with the Kikratook weaving had higher risk than other weaving types because the weaver raised the shoulder and exerted the arm throughout the operation.

In summary, traditional weaving was found to have the least ergonomic risk among the types of weaving investigated. The highest risk to both hands was found in Kikratook weaving, due to the requirement for simultaneous and rhythmical exertion of the hands. Teen Chok weaving required more right hand activity than other weavings. Teen Chok weaving requires use of the right hand to lift interlaced yarns into a pattern and weaved a complex pattern. The ergonomic risk assessments of all three methods were likely to give similar results, except RULA which was unable to analyze the difference of individual weaving. SI is more difficult and complex than the ACGIH-HAL and RULA. The subjective assessment is a simple method, evaluated by observation, expert estimation, or worker self-report. Specific checklists or questionnaires were employed in most subjective evaluations. Available assessments of occupational ergonomics risk are both objective and subjective assessments, but subjective assessments have been more frequently used. For weaving work, both hands were considered at risk and working condition improvement was necessary to redesign the workstation and tool design in home weaving with special consideration of the anthropometric profile of the user group and neutral posture in reducing muscle activities, such as, shoulders being abducted and raised in Kikratook weaving and neck flexion and twisting in Teen Chok weaving.

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