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Workstation improvement to reduce muscle aches during silk degumming and dyeing in silk weaving profession in Nakhon Ratchasima province

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Abstract

Silk degumming and dyeing are considered high ergonomics risk procedures for workers because they have to stand working, bent and perk their faces, twist their bodies, and wrists during the processes. These affect the Surface Electromyography (sEMG) especially the lower back which is a significant problem affecting the production efficiency, and workers' health and safety. This study aims at improving the workstation to reduce muscle aches during silk degumming and dyeing in the silk weaving procession in Nakhon Ratchasima province. The data was collected using anthropometric measurements for standing work on 400 workers in silk degumming and dyeing. The data was used to improve the degumming and dyeing aid equipment. The study found that degumming and dyeing using the traditional degumming and dyeing equipment gave a higher sEMG rate and amplitude of upper trapezius muscles than the degumming and dyeing aid equipment. This meant higher tissue load and muscular fatigue. This could reduce the time for the silk degumming and dyeing at the rate of 30.09%.

Keywords: Silk degumming and dyeing, Safety at work, Workstation, Surface electromyography (sEMG)

1. Introduction

Handicraft is an important industry to developing countries; it is a small industry in the countryside that needs a lot of workers most of whom are women. Most handicraft industries use instruments made of wood that need traditional working postures that are not ergonomically correct [1] thus muscles and skeleton are affected; especially the shoulders which in turn reduces the working efficiency [2]. Musculoskeletal disorder (MSD) is the most widely recognized illness found in the business. It related the medical issue in India with nearly one out of four laborers suffering spinal pain, and one out of five grumblings of strong torments. According to the illness mentioned above, it was considered that the objects lifting, holding, putting down, pushing, pulling, conveying, or developing of a heap, were the biggest reasons for damaging parts of workers. Good care takes could reduce the injury caused by the musculoskeletal disorder which some of the intense injury, such as, cuts or breaks due to accidents in woking [3]. The MSD prevalence was significantly correlated with education background, working period, prolonged sitting hours, work posture and weavers' anthropometry [4].

Weaving is considered one of the important household industries in some developing countries, such as China, Bangladesh, Turkey, Pakistan, Iran, and India. Weaving is still done traditionally, and it is the world's oldest method [5]. Weaving is a countrywide occupation in Thailand but the most famous silk is made in the northeastern part of Thailand [6]. 15,230 agriculturists grow mulberry and weave silk in Nakhon Ratchasima. The silk products were sold for 4,563 million baht in 2018 [7]. Dangers that occur in the weaving industry are mechanical, physical, chemical, and physiological dangers [8].

The ergonomically designed workstation is a solution to ergonomic and productivity problems in the workplace [9]. It is necessary to understand the steps of the handicraft industry and ergonomically improve the working process because the problems of ergonomics are important to business and workers' good health [10, 11]. Type of handloom, rest, working postures, daily working hours, etc. are the most important and considerable factors which were directly associated with the prevalence of musculoskeletal disorders among handloom weavers. The majority of ergonomic shortcomings and important factors for musculoskeletal symptoms in weaving operations originated from ill-designed weaving workstations [12]. Overall, it can be concluded that the female weavers were significantly influenced by the use of ineptly designed workstation and hand tools [13]. The procedure of appropriate ergonomics in workstation was conducted to have workers in good health, be convenient, and be able to work effectively [14].

The result of the study on the factors affecting musculoskeletal disorders in workers of the degumming and dyeing process of silk weaving profession in Nakhon Ratchasima Province found that the silk weaving professionals had problems of muscle aches with the most affected areas being the right shoulder, left shoulder, lower back, right elbow, neck, and left elbow. Factors affecting the musculoskeletal disorders found were: 1) the body mass index, 2) weighing down on one side of the body, 3) reaching above the shoulder to pick up or hold the material, 4) continuous bending down of their heads to work, 5) repetitive raised neck or back during work [15]. According to the information mentioned above, researchers were interested in studying and improving the workstation to

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reduce muscle aches due to silk degumming and dyeing of the silk weaving process in Nakhon Ratchasima province. The result of this study would help in planning the improvement and reduce workers' skeletal and muscular system anomalies in the silk weaving process.

2. Materials and methods

The research was made in the following processes:

2.1 Cross-sectional analytic study

The population in this study was 4,180 workers in the degumming and dyeing process as shown in Figure 1. Krejcie and Morgan's table for determining sample size was used to calculate the sampling [16] of 400 workers(female)made with simple random sampling. Draw lots were made to give chance to all samples to get selected fairly. The workers were then informed about the objectives and the process of the research, and the data of anthropometric measurements for standing work [17].

Figure 1 Degumming and dyeing process

2.2 Workstation improvement

Workstation improvement to reduce muscle aches due to silk degumming and dyeing of silk weaving profession (Degumming and Dyeing Process) was conducted with the use of ECRS (E:Eliminate, C:Combine, R:Rearrange, and S:Simplify) technique which was considered as a technique used for finding a way to develop better working process. For this study, just the E (Eliminate) and S (Simplify) were applied as follows.

1. E: Eliminate, it was conducted to cut off any time-wasting on degumming and dyeing process. It was the design of the height and width of the degumming and dyeing aid equipment appropriately to reduce the hands' movement upward above shoulders to grab the objects in working, reducing looking up and down, and the workers' backs bending.

2. S: Simplify, it was conducted with making easier process by the used of reels to reduce the use of force lifting the silk thread in dyeing

2.3 The surface electromyography (sEMG)

The surface electromyography (sEMG) was made on both left and right-side muscles to 30 of 400 workers in the degumming and dyeing process. The sample was selected by simple random sampling using draw lots.

2.4 Surface electromyography (sEMG)

Surface Electromyography (sEMG) was the tool used for measuring the muscles used workers suffered at work. It emphasized the upper trapezius or upper extremity muscles [18, 19]. The measurement was conducted on both modern and traditional working methods. The measurements were made 3 times with the BI OPAC (EMG, BIOPAC System, model BIOPAC MP 150, Inc., Santa Barbara, California). The steps for setting the electrode were as follows,

2.4.1 Applying 3 electrodes

Applying 3 electrodes (TSD 150B, BIOPAC System, Inc., Santa Barbara, CA, USA, gain=350) which were anode, cathode, and ground electrode to the left and right upper trapezius muscles. The anode and cathode were applied on the trigger point which was in the imaginary lines between the C7 spinous process and the acromion process. Both anode and cathode were applied parallel to the imaginary lines. The gap between the center electrode was 20 millimeters [18] and the ground electrode was set to the C7 spinous process. To stick the electrode to the workers, skins of workers were cleaned with fine sandpaper and alcohol to reduce the electric potential difference of the skin and increase the sensitiveness to the electrical conductivity of their skins which needed to be lower than 5-kilo ohms to be acceptable (measured with an ohmmeter) [20].

2.4.2 Electric signal

The electric signal was converted from analog signal to digital signal which showed on the computer screen by configuring the signal filter with the sampling rate = 2,000 hertz and the signal was amplified 1000 times with the bandpass filter at 10-400 hertz.

2.4.3 Surface electromyography (sEMG)

The data was collected using the surface Electromyography (sEMG) towards the muscle in the weave preparation process in both pre and post-development process. The data was collected nine hours from 8:00-17:00. Both groups were measured three times.

2.4.4 Analysis of the result of sEMG with AcqKnowledge version 4.2 software

The analysis of the result of the use of sEMG with AcqKnowledge version 4.2 software for the BOIOPAC tool gave the result of the root mean square (RMS). The sensitiveness to the electrical conductivity of workers' skins was different, so the RMS was calculated and presented in proportion to adjust the normalized waveform [21, 22]. The rate of RMS was compared with the maximum shrink value at the percentile of 10, 50, and 90 of workers in the silk preparation process in both pre and post-development as the representative of work format in static load, median load, and peak load, respectively [23].

2.5 Data analysis

General data analysis and the sEMG were made with descriptive statistics which were mean, standard deviation, and t-test Statistic with Minitab 17 software.

3. Results

3.1 Ergonomically designed workstation

The anthropometric measurements for the 400 females were recorded as shown in Table 1. The measurements were taken to help design a new workstation for the workers to help them work more ergonomically. For example, the calculation of standing height.

Table 1 Anthropometric measurements for standing work (N=400)

No.	Body dimensions	Min (cm.)	Max (cm.)	female percentile		Mean (cm.)	SD (cm.)
				5th (cm.)	95th (cm.)		
1	Standing height (Stature)	138.2	176.89	143.73	170.66	157.18	20.32
2	Standing eye height	133.92	163.88	137.66	156.60	146.98	32.15
3	Standing shoulder height	113.04	143.03	119.57	139.30	129.33	12.43
4	Standing elbow height	82.55	113.12	85.08	108.14	97.61	20.35
5	Hip height	33.93	61.60	35.96	59.95	46.01	25.26
6	Knuckle height	53.48	80.74	58.01	77.20	67.97	31.43
7	Fingertip height	37.53	64.49	44.06	60.45	51.48	24.41
8	Knee height	31.44	62.50	35.66	59.96	48.53	16.32
9	Forearm/Arm span	46.1	65.49	52.14	60.90	55.58	21.39
10	Chest height	85.06	114.65	92.55	108.64	99.03	11.46
11	Waist height	85.53	107.03	89.51	103.26	94.58	21.38
12	Shoulder width	31.93	54.49	34.52	50.18	41.16	17.47

3.1.1 Standing shoulder height: height of workstation using K as values from z-score:

K = -1.64 for 5% percentile below mean
K =1.64 for 95% upper mean.

Therefore, Distance height	= Standing shoulder height±K.(SD)
5^{th} percentile (Min)	= 129.33- (1.64).(12.43)
	=120.46 cm.
95^{th} percentile (Max)	= 129.33+ (1.64).(12.43)
	= 138.20 cm.

3.1.2 Arm span: height of workstation using K as values from z-score:

Therefore, Distance height	= Arm span ± K.(SD)
5^{th} percentile (Min)	= 55.79 - (1.64).(6.29)
	= 45.47 cm.
95^{th} percentile (Max)	= 55.79 + (1.64).(6.29)
	= 66.11 cm.

3.1.3 Shoulder width: width of workstation using K as values from z-score:

Therefore, Distance height	= Shoulder width ± K.(SD)
5^{th} percentile (Min)	= 41.16 - (1.64).(4.47)
	= 33.83 cm.

95th percentile (Max) = 41.16+ (1.64).(4.47)
= 48.49 cm.

Workstation improvement to reduce muscle aches during the silk degumming and dyeing process with the degumming and dyeing aid equipment is shown in Figure 2. With the design of having a support base for degumming and dyeing tank and gas cylinder which was used as fuel for boiling water in degumming and dyeing. There was a set of air ventilation tool to take out smoke occurring in the degumming and dyeing process. Moreover, there was a pulley assisting in reducing the use of force in lifting things in the process for workers.

Designing the height of the degumming and dyeing aid equipment = Standing shoulder height ± Arm span
= 165.93 cm. (5%) Min to 204.31 cm. (95%) Max

The height of the degumming and dyeing aid equipment should be between 165.93 and 204.31 cm. which could reduce the hands' movement upward above shoulders to grab the objects in working, reducing looking up and down, and the workers' backs bending.

Designing the length of the shaft = Shoulder width
= 33.83 cm. (5%) Min to 48.49 cm. (95%) Max

The length of the shaft was made between 33.83 and 48.49 cm which allowed both hands to move out horizontally and fit the should width. The helps to make the movement of the upper and lower part arms in lifting the objects up and down could be done without the use of shoulders and body movement. This could reduce the neck ache, backache, shoulder ache, and wrist ache. Moreover, the equipment was flexible for workers as it could be arranged to suit the manufacturing process requirement.

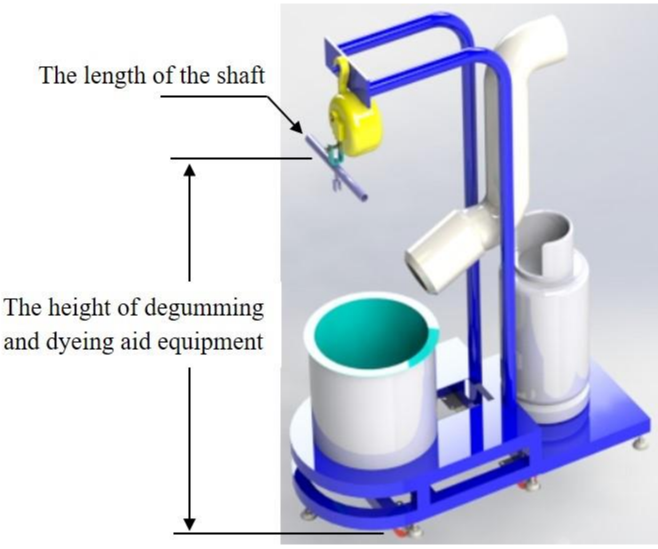

Figure 2 Degumming and dyeing aid equipment in the weaving process (petty patent number 15844)

3.2 Measuring muscles used in working with surface electromyography (sEMG)

The average rate and standard deviation of used muscles of workers' sEMG amplitude distribution were at the percentile rate of 10, 50, and 90. The right and left trapezius muscles showed greater 10thsEMG amplitude distribution (P<0.01) significantly, 50thsEMG amplitude distribution (P<0.01), and 90th sEMG amplitude distribution (P<0.05) muscle activation with the result of the use of the traditional degumming and dyeing equipment as compared to the degumming and dyeing aid equipment. The study found that degumming and dyeing using the traditional equipment gave a higher sEMG rate and amplitude of upper trapezius muscles than the degumming and dyeing aid equipment. This meant higher tissue load and muscular fatigue as shown in Table 2.

Table 2 The average rate and standard deviation of used muscles of workers for right and left upper trapezius muscles at degumming and dyeing process with degumming and dyeing aid equipment and traditional degumming and dyeing equipment (N=30)

Upper trapezius	percentile	Traditional degumming and dyeing equipment mean (StDev)	degumming and dyeing aid equipment mean (StDev)
Right (RVC %)	10	[aa,bb]13.80 (0.64)	7.50 (0.32)
	50	[aa]24.60 (0.96)	14.10 (0.32)
	90	[a]51.30 (0.99)	[b]41.50 (1.01)
Left (RVC %)	10	14.20 (1.04)	7.10 (1.12)
	50	[aa,bb]27.30 (1.21)	[aa]15.50 (1.25)
	90	[aa]54.50 (1.04)	42.30 (0.48)

[a]P<.05; [aa]P<.01; [aaa]P<.001; traditional degumming and dyeing equipment vs. degumming and dyeing aid equipment
[b]P<.05; [bb]P<.01; [bbb]P<.001; right vs. left side
EMG=electromyography; RVC=reference voluntary contractions

Figure 3 shows the development of the degumming and dyeing aid equipment. This could change the way of working which helped to reduce the hands' movement upward above shoulders to grab the objects in working, reducing looking up and down, and the workers' backs bending.

(a) Traditional degumming and dyeing equipment [15] (b) Degumming and dyeing aid equipment (New)

Figure 3 Degumming and dyeing process

3.3 The result in terms of the time of degumming and dyeing

According to Figure 4, the result of the statistical analysis to find out the difference of time of degumming and dyeing with traditional tools and the developed instruments was made with 30 sets of data. The test was made with a t-test with a 95% confidence interval (α=0.05) with the following hypothesis,

μ_1 refers to the average time of the degumming and dyeing aid equipment

μ_2 refers to the average time of the degumming and dyeing process

H_0: $\mu_1 - \mu_2 = 0$

H_1: $\mu_1 - \mu_2 \neq 0$

Difference = mu (New) - mu (traditional)

Estimate of the difference: -34.66

95% CI for the difference: (-28.78, -40.54)

T-Test of the difference = 0 (vs not =):

T-Value = -12.06 P-Value = 0.000 DF = 39

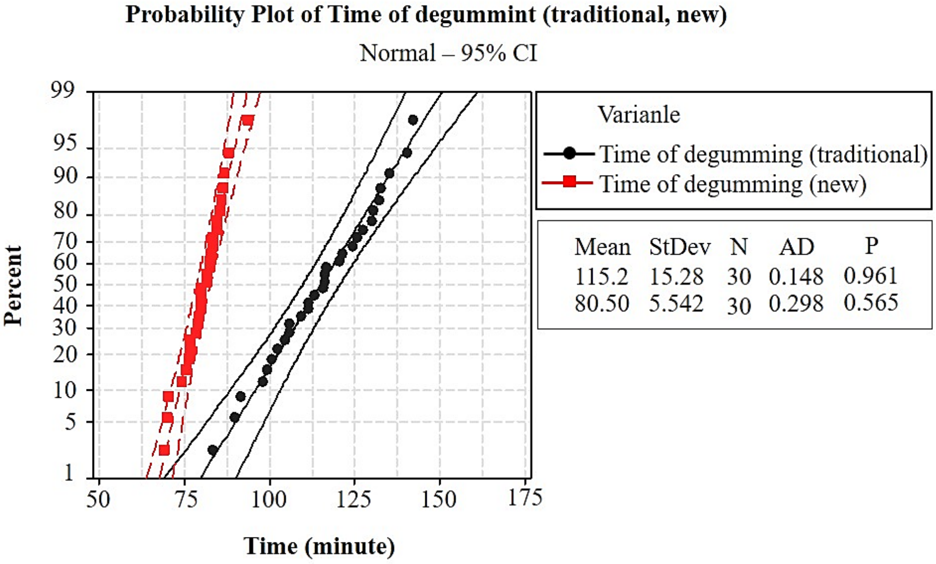

Figure 4 Time of degumming and dyeing (traditional vs new equipment)

The result found after the test showed that the P-value was 0.000 which was less than 0.05. This showed that the average time of degumming and dyeing using the traditional tool and developed instruments were significantly different. The average time of degumming and dyeing using the traditional tool and developed instruments were different by 34.66 minutes (estimate of the difference) and the confidence interval for difference (CI for difference) was between 28.78 to 40.54 at the 95% confidence interval which could reduce the degumming and dyeing time by 30.09%.

4. Discussion

The textile and apparel industry is considered one of the most leading segments of the economy in the country. Ergonomics is the application systematically of principles, methods, and data obtained from various kinds of disciplines to develop a system that people play a significant role. In the current garment industry, many operations occurred in the production process are found that they are repetitive, and this kind of repetition causes musculoskeletal disorders. Then it is important to consider finding a solution to terminate the causes of this disorder and enhance the safe and healthy workplace for the workers [24]. The part of the body that were usually affected by musculoskeletal disorders (MSDs) were elbows, wrists, hands, shoulders, the neck, and back. The disorders led to weakness, pain, and loss of strength. MSDs are considered a major health problem in the workplace. They became the leading cause of occupational diseases in the garment sector [25]. The condition in working, poor workstation design, and seats are the risks for sewing machine operators. Repetition, the force used, posture and vibration are also factors affecting higher injury [24]. It became undisputed that ergonomics could lead to good business sense. A lot of companies were aware of it and tried making changes in their workplaces to prevent injury of their workers (proactive ergonomics) as the prevention was considered as cost-effective payment for preventing the risk of their workers in their workplaces before it happened, and they had to pay more for healing [26].

The result of the study showed that degumming and dyeing using the traditional degumming and dyeing equipment gave a higher sEMG rate and amplitude of upper trapezius muscles than the degumming and dyeing aid equipment. This meant higher tissue load and muscular fatigue. The study conducted by Colovic [19], showed that stressed working due to the restricted mobility of the workers' legs on sewing machines, and the posture that was not appropriate affected both their health and efficiency of the production process. The result of workstation improvement to reduce muscle aches due to silk degumming and dyeing of silk weaving profession with the development of degumming and dyeing aid equipment could reduce the degumming and dyeing time by 30.09 %.

In clothing industry in the South African, there were numerous workplaces paid more attention to the ergonomic management. The ergonomic principles were applied in developing workplace in both simple and innovative ways as well as creative thinking to improve the condition of their industry [27]. Ergonomics play an important role describing the conflict between man and machine in working. It helps developing ideas of placing man to the appropriate components as a single system to work in a synchronized manner with other. These components were considered as workers and work environment in terms of the physical and organizational, the task, and the workspace. Therefore, the well workplace management with the consideration of the ergonomic risk factors could be crucial first steps in preventing dangers and increasing worker protection [28].

5. Conclusions

To summarize, a study on the improvement of the workstation to reduce muscle aches due to silk degumming and dyeing of silk weaving profession using the data of anthropometric measurements for 400 standing workers was conducted as basic information for the development of degumming and dyeing aid equipment. The study found that degumming and dyeing using the traditional degumming and dyeing equipment gave a higher sEMG rate and amplitude of upper trapezius muscles than the degumming and dyeing aid equipment. This meant higher tissue load and muscular fatigue. The developed tool could reduce the degumming and dyeing time by 30.09 %.

The result of this study would be advantageous for developing a working method that is ergonomically correct to reduce the muscle aches of workers. This study aimed at the need to conduct the development based on the consideration of the appropriate ergonomics in improving workstation so that it helped to increase the work efficiency, safety, and convenience of workers in degumming and dyeing process in the silk weaving profession.

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