Natural Resources for Human Health
eISSN: 2583-1194

Original Research

Received 18 Aug 2026
Revised 09 Sep 2026
Accepted 27 Sep 2026

Natural Resources for Human Health 2026, Vol. 6 (23s): 972–983

KEYWORDS:
Occupational health; older worker; ergonomics; health science; well-being.

Redesign and Evaluation of Handloom Workstations for Older Weavers Based on Anthropometric Data

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ABSTRACT: Mismatch between weavers' anthropometric dimensions and their workstations, tools or equipment can lead to muscle discomfort, fatigue and musculoskeletal injuries, especially among older workers. This study examined the impact of redesigning handloom workstations based on older weavers' anthropometric dimensions on muscle activity. Methods: Thirty-one anthropometric dimensions of 24 older weavers aged 60 years or above were measured, and their descriptive statistics (means, standard deviations, coefficients of variation, and 5th, 50th and 95th percentile values) were calculated. The data were used to produce a prototype of a redesigned handloom. Each participant was randomly assigned to either the traditional-handloom workstation and the redesigned-handloom workstation, and the muscle activity of their right upper trapezius (UT), biceps brachii (BB) and flexor digitorum profundus (FDP) were measured using electromyography (EMG). Results: The percentage of maximum voluntary contraction (%MVC) values were 45.38% and 50.05% for the right UT, respectively; 13.02% and 16.60% for the BB; and 27.71% and 29.19% for the FDP. The UT exceeded the acceptable %MVC threshold of 30% in both workstations. The mean %MVC values for the UT and BB were significantly higher in the redesigned workstation ($p < 0.01$), while the FDP activity did not differ significantly between workstations. Conclusions: Designing handloom workstations to match the anthropometric dimensions of older weavers is essential for reducing their musculoskeletal risk and enhancing their work performance and well-being.

1. INTRODUCTION

Handloom weaving is a revenue-generating industry in many Asian countries, such as Bangladesh (Moshiur Rahman et al.), India (Das et al., 2020; Durlov et al., 2014; Pandit et al., 2013), Indonesia (Muhamad Ramdan et al., 2020), Iran (Choobineh et al., 2004; Motamedzade & Moghimbeigi, 2012), and Thailand (Noyming et al., 2023). In Thailand, where over 20% of the population is aged 60 or older (Department of Older Persons, 2024), both government and private-sector initiatives encourage older adults in rural areas to participate in the industry by transforming their traditional weaving knowledge into culturally inspired textile products that enhance their livelihoods through community enterprise models (Parmotmuang, 2025). According to (Meher et al., 2025; Sombatsawat et al., 2025; Wewa & Khucharoenphaisan, 2023), older women produce more than 80% of traditional weaving products. Although traditional weaving is considered low-paying, household-based informal labour and self-employment in several developing countries (Meher et al., 2025), it sustains older women's active engagement with life as healthy, productive members of society, providing them with a sense of purpose and self-respect (Willcox et al., 2007).

Traditional handlooms are operated manually, with techniques passed down through generations (Ramratan et al., 2022). The most common types include pit looms, fly-shuttle looms and backstrap looms in northern Thai regions (The Thai Fabric Chronicles, 2019). They require significant manual skill, from setting up the loom to threading and weaving (Zainab & Nikhila, 2025). However, many weaving tasks are performed under uncontrolled and unsafe conditions, leading to injuries, illness and even fatalities related to musculoskeletal disorders (MSDs) (Koiri, 2020; Yota et al., 2025). Ramdan (2020) reported that MSD prevalence among female weavers is 85.5%. (Iwan et al., 2019) found that MSDs in Samarinda Sarong weavers in Indonesia might have been caused by poor work posture due to non-ergonomic handloom design. Work posture can be defined as the orientation of a worker's body parts in the work area while performing a task (Nico J. Delleman et al., 2004; Raemy et al., 2015). Thus, it is determined by the characteristics of the worker, the workstation and the work process (Adellian, 2024; Health Service Executive, 2024; Iwan et al., 2019; Motamedzade et al., 2014) From literature review have indeed identified associations between MSDs and work posture, along with prolonged sitting time and body anthropometry. Studies in several countries (Choobineh et al., 2004; Durlov et al., 2014; Moshiur Rahman et al., 2017; Motamedzade & Moghimbeigi, 2012) have revealed a high prevalence of MSDs in different body regions. Weavers, in particular, are exposed to many of the recognised risk factors for shoulder MSDs, including repetitive tasks, lack of a work–rest regime and prolonged stooped and awkward arm and shoulder postures (Motamedzade et al., 2014). Mahantare and Thakre (2026) highlighted the importance of ergonomic solutions such as workstation redesign, pedal mechanism optimisation, and posture correction, which can dramatically reduce musculoskeletal risks.

A previous study among women handloom weavers in Thailand found that the three body parts with the highest prevalence rate of MSDs were shoulder (68.00%), knee (63.30%), and upper arm (54.7%). Working postures were classified as having medium risk with 44.0% (Sombatsawat et al., 2025). Many studies concluded that in carpet weaving, poor workstation design – especially when inappropriate for the anthropometric dimensions of weavers – is a major risk factor for MSDs symptoms. (Choobineh et al., 2007; Karimi et al., 2016; Khan & Qayum, 2024; Motamedzade & Moghimbeigi, 2012). According to Chantaramanee et al. (2015) weavers reported pain most frequently in their backs, necks and shoulders. These findings highlight the importance of incorporating anthropometric data into workstation and tool design. Therefore, this study used anthropometric data of older weavers to redesign a handloom-weaving workstation that would match their body dimensions, thereby reducing MSD risk. Lee (2019) suggested that MSDs risk for older weavers may be reduced by ergonomically redesigning products, workplaces and facilities using appropriate anthropometric data. Applying anthropometric data to the design of handlooms for older Thai women is critically important for achieving functional efficiency, ease of use, comfort, health and safety (Kaewdok et al., 2020). This aligns with the finding of Iwan (2019) that traditional handlooms used by Indonesian female weavers were incompatible with their anthropometric dimensions.

Occupational ergonomics is a multidisciplinary perspective for promoting safety and health through effective work design. In modern times, ergonomists collaborate with other occupational health professionals to design jobs that fulfill the three most important qualities of humans: capabilities, limitations, and requirements. The objective of occupational ergonomics is to build a safe and healthy environment for workers which, in turn, will enhance productivity (Gangopadhyay, 2022). Anthropometric data are used in ergonomics to specify the physical dimensions of workspaces, equipment, furniture and clothing to ensure that physical mismatches between the dimensions of equipment and products and the corresponding user dimensions are avoided (Bridgers, 2026). Anthropometry is essential for designing safe products, tools, and work stations that deal with body measurements, particularly those of size, shape, and body composition (Kaewdok et al., 2022). Musculoskeletal disorders (MSDs) involving the soft tissues of the body – the muscles, tendons, ligaments, joints, nerves, cartilage and supporting structures of the body with common symptoms as pain, discomfort, weakness, tingling, swelling, and numbness (Bridgers, 2026; Gangopadhyay, 2022).

However, the literature provides limited evidence of such data for the ergonomic design of handloom workstations for older weavers in Thailand. This study is based on the principles of ergonomics, which focus on understanding the interactions among human characteristics, capabilities and limitations in the workplace. Ergonomics encompasses aspects of work, posture, tools and equipment, and the overall work environment. It is often referred to as occupational ergonomics, as it is a key component of occupational health and safety, aiming to promote employee health, efficiency and well-being by designing for safe, satisfying and productive work (International Ergonomics Association (IEA), 2010). Therefore, this study determines relevant anthropometric data for ergonomically redesigning handloom workstations and evaluates the effects of the redesigned workstations on the muscle activity of older weavers.

2. MATERIALS AND METHODS

2.1 Study participants

Twenty-four female handloom weavers were recruited. The inclusion criteria were as follows: (1) aged 60 or older (2) good health, with neither MSDs nor a history of rheumatological disease; and (3) availability and willingness to participate voluntarily, without payment or other forms of reward.

2.2 Study extraction Procedure

Phase 1: Measurement of anthropometric dimensions

Data on 31 anthropometric dimensions, including body weight, were collected from the participants (Table 1). These dimensions were selected for their relevance to the ergonomic redesign of the handloom, following ISO 7250-defined basic human body measurements for technological design (International Organization for Standardization, 2008). Anthropometric measurements were conducted to obtain body dimension data relevant to the ergonomic design and adjustment of handloom workstations for older weavers. The measurements were selected based on their relevance to working posture, workstation dimensions, reach requirements, and the interaction between the workers and handloom equipment. All measurements were performed using standardized anthropometric measurement procedures under consistent conditions (International Organization for Standardization, 2008). The participants were informed about the measurement procedures before data collection and were asked to wear light-fitting clothing and remove footwear and bulky accessories, where appropriate, to minimize potential measurement errors. To minimize intra-observer and inter-observer variability, the same measurement protocol was applied consistently throughout the data collection process. Measurements were performed by trained five assistant researchers using the same instruments and standardized positioning procedures to perform the measurements using validated techniques to maximise precision, reliability and accuracy. A manual Martin-type anthropometer (Model PM. Serial number 052876, Japan) was used to measure body dimensions in standing and sitting postures. A sliding caliper was employed to measure small breadths and depths of body segments, such as hands and feet, while a measuring tape was used to manually record body circumferences with an accuracy of 1.0 mm. Body weight was measured using a digital weighing scale with an accuracy of 0.1 kg.

Phase 2: Design of an ergonomic handloom workstation

In this study, a new workstation was designed based on the recommendations of Motamedzade et al (Motamedzade et al., 2014). Standing elbow height was used to determine the proper shuttle-handle height, ensuring that the operator could remain erect while operating. The optimum sitting height was adjusted according to the popliteal dimension, with the seat height recommended to be close to the popliteal height. Sufficient space was provided under the span value so that older weavers could extend their hands comfortably. Using the anthropometric data collected in Phase 1, a prototype handloom workstation was designed to minimise muscle activity associated with MSDs among older weavers, are presented in Table2.

Phase 3: Evaluation of the redesigned handloom workstation

The participants were randomly divided into two weaving groups: Group A, assigned to the traditional-handloom workstation (Figure 1), and Group B, assigned to the redesigned-handloom workstation (Figure 2).



Figure 1. Traditional-handloom weaving workstation.

Natural Resources for Human Health
eISSN: 2583-1194

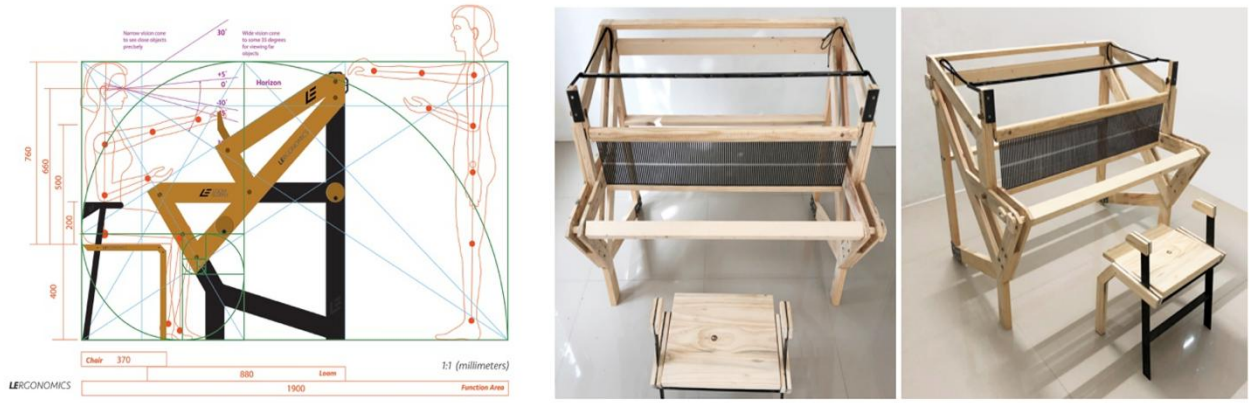


Figure 2. Prototype of weaving workstation with the handloom redesigned based on the older weavers' anthropometric data.

After receiving training in practical weaving to ensure the use of uniform weaving techniques, the participants were asked – in a random sequence – to perform continuous weaving for 20 minutes at their assigned try both workstations. In which case they first wove for 20 minutes in one workstation, rested for 10 minutes to minimise fatigue effects, then wove in the other workstation for 20 minutes. During which electromyography (EMG) data were collected.

For the data collection, two bipolar surface electrodes with a 20 mm inter-electrode distance were placed on each of three muscles – the right upper trapezius (UT), biceps brachii (BB) and flexor digitorum profundus (FDP) (Figure 3) – following established protocols (Florimond V, 2008; Lim et al., 2024). Placement of the electrode on the muscles was based on the literature study as the UT: midway between the seventh cervical vertebrae (C7) and acromion, the BB: between the muscle endplate region and the distal tendon insertion (muscle belly), and the FDP: 5–7 cm from the distal to the line connecting the bicep tendon and medial epicondyle (Shankar S et al., 2021).

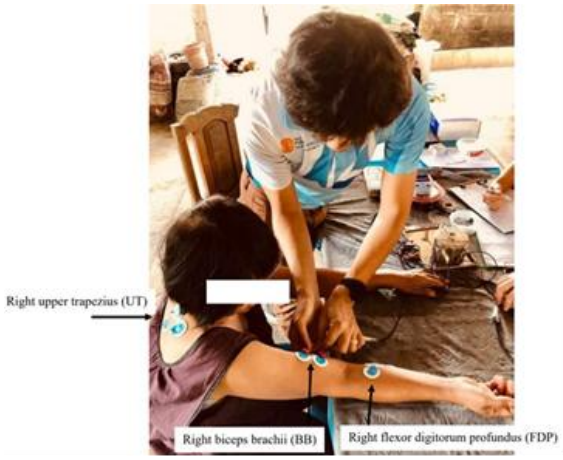


Figure 3. EMG electrodes placement.

These muscles were chosen for their relevance to repetitive weaving tasks (Meher, 2025; Motamedzade, 2014). The skin was cleaned with alcohol and shaved. The electrodes were connected to a data logger that simultaneously recorded surface EMG signals using using Megawin 3.0 software (MEGA WIN, version ME6000, Biomonitor, Kuopio, Finland) (Aalto Behavioral Laborator, 2016). The signals were digitised at 1,000 Hz, stored on a compact flash memory card and later downloaded to a personal computer for analysis.

The root mean square (RMS) values were calculated for each muscle to quantify the muscle strength and fatigue. To normalise the signals, three maximum voluntary contraction (MVC) trials were performed for each muscle, each lasting 5 s. (Alhaag et al., 2024; Konrad P, 2005). The average RMS values from these three trials were used as the reference values (Motamedzade et al., 2014).

2.3 Statistical Analysis

Descriptive statistics of the participants' anthropometric data were calculated, including the 5th, 50th and 95th percentile values and the coefficients of variation (CV). A paired t-test was used to evaluate differences in the means and SD of the %MVC values between the two workstations. Statistical significance was set at $p < 0.05$.

3. RESULTS AND DISCUSSION

3.1 Demographic and anthropometric dimensions of the older weavers

The participants were all women with a mean age of 66.50 ± 6.30 years and a mean work experience of 12.50 ± 5.80 years. The average of weight of 50.75 ± 8.30 kg., height of 151.17 ± 4.91cm., Body Mass Index (BMI) of 24.86 ± 3.59 kg/m2. The 5th, 50th and 95th percentile values, along with the CV (expressed as %) for each of the 31 measured anthropometric dimensions, are presented in Table 1.

Table 1. Dummy Experimental Data Percentile values (5th, 50th and 95th) and coefficients of variation (CV) of 31 anthropometric dimensions of Thai weavers aged 60 or older (n = 24).

Anthropometric dimension	Percentile value (cm)			CV (%)
	5th	50th	95th	
Standing measurement				
1. Weight	37.40	51.60	70.12	18.24
2. Stature	140.50	149.00	160.50	3.89
3. Eye height	130.00	139.00	149.50	11.04
4. Shoulder height	114.00	122.00	130.00	7.84
5. Elbow height	84.50	92.00	99.00	8.98
6. Hip height	85.00	92.00	98.00	5.29
7. Knuckle height	55.25	63.00	68.00	7.12
8. Fingertip height	49.00	55.00	60.00	14.92
9. Span	136.00	152.00	165.00	7.37
10. Elbow span	59.50	74.00	86.00	21.94
11. Vertical grip reach	111.50	178.00	189.50	13.64
12. Forward grip reach	53.50	60.00	66.00	6.52
13. Forward fingertip reach	60.50	66.00	72.50	5.80
Sitting measurement				
14. Sitting height	70.00	76.00	83.00	5.77
15. Eye height	59.50	66.00	73.00	6.99
16. Shoulder height	44.00	50.00	56.00	7.36
17. Elbow height	16.00	20.00	29.00	24.03
18. Knee height	42.00	47.00	50.00	7.73
19. Popliteal height	35.00	40.00	42.00	5.29
20. Buttock–knee length	40.00	46.00	54.50	12.32
21. Buttock popliteal length	32.25	37.00	44.00	15.81
22. Chest (bust) depth	12.00	16.00	22.50	22.85
23. Shoulder breadth	32.00	36.00	41.00	8.70
24. Hip breadth	21.00	33.00	38.00	15.12
Other measurements				
25. Upper arm length	25.00	30.00	34.00	9.51
26. Forearm hand length	36.00	40.00	45.00	7.60

Anthropometric dimension	Percentile value (cm)			CV (%)
	5th	50th	95th	
27. Hand length	15.35	17.00	18.00	6.65
28. Hand breadth	7.00	7.50	8.50	51.75
29. Grip diameter (inside)	2.75	3.50	4.50	47.89
30. Foot length	20.05	22.00	24.65	7.83
31. Foot breadth (horizontal)	8.00	9.00	10.00	63.76

3.2 Application of anthropometric data to the design of an ergonomic handloom workstation prototype

The application of the anthropometric data to the redesign of the handloom workstation for older weavers, along with the design criteria used. The 5th, 50th, and 95th percentile values were used as anthropometric references for determining the dimensions of the redesigned handloom workstation. These percentiles were selected to account for variations in body dimensions among older weavers and to improve the suitability of the workstation for users with different anthropometric characteristics. The selection of percentiles followed established ergonomic design principles. The 5th percentile (P5) was primarily considered for reach-related dimensions to ensure that workstation components could be accessed by individuals with relatively smaller body dimensions and shorter reach distances. The 95th percentile (P95) was considered for clearance-related dimensions to provide sufficient space for individuals with relatively larger body dimensions. The 50th percentile (P50) represented the median anthropometric characteristics of the study population and served as a reference for determining dimensions where accommodating the median user was appropriate.

The selected anthropometric measurements were translated into specific workstation dimensions according to their functional relevance. For example, popliteal height was considered when determining seat height, buttock-popliteal length when determining seat depth, and hip breadth when establishing seat width. Sitting elbow height was used as a reference for determining the working surface height, while functional reach measurements informed the positioning of frequently used handloom components and tools. Leg and knee clearance dimensions were determined using the larger relevant anthropometric values to provide adequate space during operation, are presented in Table 2.

Table 2. Application of anthropometric data to the design of the ergonomic-handloom workstation.

No.	Anthropometric dimension	Application to the handloom workstation redesign	Design criterion (percentile)	Value (cm)
Standing dimension				
1	Stature	For proper hand location to ensure upright posture while weaving	95th (minimum)	160.50
2	Eye height	For proper placement of items requiring visual inspection, equipment controls, display devices	5th	130.00
3	Shoulder height	For warp beam height adjustment	5th	114.0
4	Elbow height	For proper shuttle loom handle height to ensure upright posture while weaving	5th	84.50
5	Knuckle height	For proper low-level positioning of controls, handles, handrails, cloth beam	95th	68.00
6	Vertical grip reach	For proper height of overhead controls; ease of motion, reach	5th	111.50
7	Span	For sufficient workplace, handloom working space; proper weaving workstation width	95th	165.00
8	Elbow span	Upper body clearance for ease of motion, tool use	95th	86.00

No.	Anthropometric dimension	Application to the handloom workstation redesign	Design criterion (percentile)	Value (cm)
Sitting dimension				
9	Shoulder height	For harness, reed height adjustment; overall workplace layout, working area design	5th	44.00
10	Eye height	For proper levels of lever, push–pull buttons, control panels, displays; steering wheel position, orientation	5th	59.50
11	Popliteal height	For proper seat height	5th	35.50
12	Hip breadth	For proper seat width	95th	38.00
13	Buttock popliteal length	For proper seat depth	5th	32.25
14	Elbow height	For proper armrest height	5th	16.00
15	Hand length	For proper handle length in hand tools, manually operated equipment (e.g. reed, shuttle)	95th	18.00
17	Hand breadth	For proper handle breadth in hand tools, manually operated equipment (e.g. reed, shuttle)	95th	8.50
18	Hand grip diameter (inside)	For proper handle grip diameter in hand tools, manually operated equipment (e.g. reed, shuttle)	5th	2.75
19	Foot breadth	For foot-operated pedals, treadles, safety shoes	95th	10.00

The final workstation dimensions were established by considering the selected percentile values, functional requirements of handloom activities, and the need to maintain comfortable working postures. This percentile-based design approach aimed to accommodate anthropometric variability among older weavers, minimize excessive reaching and awkward postures, and improve the overall ergonomic suitability of the redesigned workstation.

3.3 Muscle activity

The muscle activity analysis for the traditional and redesigned workstations revealed mean %MVC values of 45.38% and 50.05%, respectively, for the UT; 13.02% and 16.60% for the BB; and 27.71% and 29.19% for the FDP (Table 3).

Table 3. Maximum voluntary contraction (MVC) and %MVC values of three muscles of the older weavers (n = 24).

Muscle	MVC		%MVC			
			Traditional workstation		Redesigned workstation	
	Mean	SD	Mean	SD	Mean	SD
Right upper trapezius	115.46	73.99	45.38	13.40	50.05	14.93
Right biceps brachii	358.16	201.12	13.02	7.54	16.60	9.13
Right flexor digitorum profundus	198.69	110.57	27.71	14.56	29.19	14.21

The paired t-test of the muscle activity revealed that the redesigned workstation produced significantly higher mean %MVC values than the traditional workstation for the right UT and BB ($p < 0.01$). No significant difference was observed in the FDP between the workstations (Figure 4).

Natural Resources for Human Health
eISSN: 2583-1194

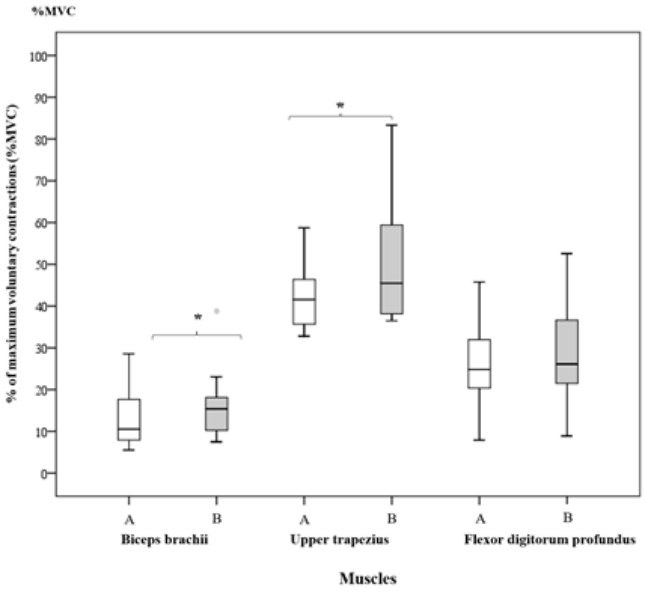


Figure 4. Muscle activity of older weavers during weaving tasks in the (A) traditional workstation and (B) redesigned workstation. *Significant difference ($p < 0.01$).

3.4 Discussion

Handloom weaving is a seated task that requires repetitive movements of specific body parts and is often performed in improper working postures (Iwan et al., 2019). To help reduce MSD risk among older weavers, this study designed an ergonomic-handloom workstation. The workstation dimensions were based on 19 of 31 measured anthropometric variables of older weavers, selected for their relevance to handloom workstation design considerations. This study confirmed that the UT, BB and FDP are actively engaged during handloom weaving. Surprisingly, however, their mean %MVC values increased in the redesigned workstation, with significant elevations for the UT and BB ($p < 0.01$). These increases suggest that although trunk posture improved, the seated weaving position increased the workload of the shoulders and upper arms. (Muhamad Ramdan et al., 2020; Shankar S et al., 2021). Notably, the UT activity exceeded the acceptable %MVC threshold of 30% in both workstations, indicating a risk of fatigue and muscle injury (National institute for occupational safety and health, 1981). In contrast, the BB and FDP activity remained within the acceptable level (Sean, 1998; Wu & Wang, 2002). This may be because the weaving process requires the repetitive actions of inserting thread into the left and right sides of the loom using shuttles and grasping the reed by alternating shoulder elevation with leaning forward. This posture repeatedly raises and moves the UT, leading to fatigue and potential injury. These findings are consistent with (Motamedzade et al., 2014), who reported similar UT activity levels (42% and 44% MVC) across workstations, and with Mahdavi (2018), who found UT fatigue dominant among 18% to 45% of carpet weavers in Iran.

Previous studies have claimed that forearm and elbow strain can be reduced through appropriate height adjustments and sufficient armrest padding. Iwan (2019) recommended setting the table surface height for female weavers using the 50th percentile of the sitting elbow height (the vertical distance of the seat to the bottom of the elbow) and the 95th percentile of the popliteal height, while (Motamedzade et al., 2014) suggested setting the backrest height according to the 5th percentile of the sitting shoulder height. The present findings support these recommendations, highlighting the importance of anthropometric data in workstation design. However, they also demonstrate that static arm elevation remains a critical risk factor even when trunk posture is optimized.

This study has several limitations. Its use of the participants' specific anthropometric dimensions to redesign the handloom restricts the direct applicability of the redesigned workstation to this sample group. Other possible limitations are the limited sample size and representativeness, age group, muscle selection, scope of weaving tasks tested and the controlled experimentation versus real-world conditions. Nevertheless, the redesigned handloom may have broader relevance for traditional weaving workstations in other regions of Thailand and across Southeast Asia, where similar anthropometric profiles are found. Moreover, while (Pritchard et al., 2019) found that during repetitive tasks, the magnitude and variability of muscle

activity are influenced by work duration, this study did not assess this aspect. Therefore, further studies should expand to more diverse samples and evaluate long term outcomes.

4. CONCLUSION

This study redesigned the traditional-handloom weaving workstation to reduce MSD risks for older weavers by applying ergonometric principles. It measured 31 anthropometric dimensions of the weavers for the redesign, thereby also providing up-to-date data, and compared activity levels of three muscles in the traditional and redesigned workstations. However, the redesigned workstation did not reduce muscle fatigue, especially in the UT. Therefore, the new design needs to be further developed to improve posture and comfort while reducing MSD risk. Nevertheless, workstation design should continue to integrate anthropometric data to minimise adverse effects of current work postures.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the handloom weavers who generously contributed their time and cooperation to this study.

AUTHOR CONTRIBUTIONS

Kamphon Saeng-iam: Investigation, Methodology, Data curation, Formal analysis, Writing – original draft, Validation, Visualization, Writing – review and editing. All of the authors have read and agreed to the published version of the manuscript.

Teeraphun Kaewdok: Conceptualization, Project administration, Resources, Software, Supervision, Funding acquisition, Investigation, Methodology, Writing – review and editing, Supervision.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

Ethics Statement

This study was approved by the Ethics Review Sub-Committee for Research Involving Human Research Subjects of Thammasat University, No. 2 (No. 042/2562). The authors declare that informed consent was obtained from each participant prior to enrollment in the study.

FUNDING INFORMATION

This research was supported by the Thammasat University Research Fund under Grant TUIN 1/2562.

Data Availability Statement

Data will be made available on request due to confidentiality issues.

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