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Original Article

Occupational risk factors related to musculoskeletal disorders among Praewa silk weavers in the Northeast region, Thailand

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Abstract

Praewa silk weavers are subject to numerous occupational risk factors that contribute to musculoskeletal disorders (MSDs), primarily due to inadequate occupational safety measures, limited access to health services, and substandard working conditions. The aim of this study was to assess the prevalence rate and determinants of MSDs among Praewa silk weavers. A cross-sectional study employing a convenience sampling method was conducted, involving 198 Praewa silk weavers from four provinces in the Northeast region of Thailand. Data collection was facilitated through a two-part research tool. The first part included a questionnaire assessment using demographic information, workplace conditions, and self-reported MSDs. The second part involved an ergonomic risk assessment using rapid upper limb assessment (RULA) and hand activity level (HAL). Descriptive statistics and multiple logistic regression analyses were conducted to determine the prevalence and associated factors of MSDs among participants. The findings revealed that the prevalence rates of MSDs in the past 7 days and 12 months were 68.68% and 96.46%, respectively. The highest prevalence rates of MSDs (over 60.00%) were observed in the wrists, fingers, and neck, with similar trends reported in both the past 7 days and 12 months. Key factors associated with MSDs over the past 12 months included low hand strength test results (adjusted odds ratio (AOR)=2.09; 95%CI: 0.44–11.05), quite low hand strength test results (AOR=2.49; 95%CI: 0.29–21.15), weaving experience of 21–30 years (AOR=1.07; 95%CI: 0.20–5.64), age between 31–40 years (AOR=2.63; 95%CI: 0.49–13.91), age above 41 years (AOR=1.13; 95%CI: 1.08–1.19), RULA level 4 (AOR=3.62; 95%CI: 0.66–19.96), and HAL score exceeding 0.78 (AOR=0.63; 95%CI: 0.80–0.98) were significantly associated with MSDs during the past 12 months. This study highlights the high prevalence of MSDs among Praewa silk weavers, attributed to occupational risk factors such as low hand strength, high hand activity level, extensive weaving experience, and poor working posture. The weaving process itself is a significant contributor to these disorders. In conclusion, ergonomics interventions aimed at preventing MSDs, including postural training, injury prevention programs, and re-designed pull-cloth devices, are recommended to mitigate these risks.

Keywords: Ergonomics, safety, well-being, decent work, musculoskeletal disorders

Introduction

Thailand has a total workforce of 37.5 million people, with 20.4 million engaged in informal employment which constitutes 54.3% of the total workforce. Among them are skilled workers totaling 17.1 million people, representing 45.7%. These individuals are employed in various

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enterprises and contribute to the public sector and businesses [1]. According to the health status data for the working-age population from the Medical and Health Information System of the Ministry of Public Health in the year 2019, the situation of health problems and hazards related to certain occupations is notable. The majority of informal laborers face issues such as heavy workloads, irregular employment, and health problems. Additionally, there are challenges in accessing health promotion and disease prevention services, as well as health hazards arising from occupational activities, which are considered significant problems [2]. Furthermore, safety concerns in the workplace and environmental conditions during work are highlighted. In addition, other informal labor groups are significant, particularly those involved in the production of textile products. The characteristics of the workers and the work environment in this group may pose risks leading to occupational illnesses, especially musculoskeletal issues. Factors contributing to abnormal conditions in the skeletal and muscular systems due to work include tasks that require excessive force, working in unnatural postures, repetitive work over extended periods, and exposure to vibrations during work [3]. It has been found that the working environment for informal labor groups also faces challenges in terms of ergonomics at work, with the highest percentage (45.0%) indicating minimal changes in posture and work ergonomics [2].

Musculoskeletal disorders (MSDs) refer to impairments of the body structures, such as muscles, joints, tendons, ligaments, and nerves, which are caused or aggravated primarily by the performance of work and by the effects of the immediate environment in which work is carried out [4]. Engaging in incorrect work practices can lead to harm among silk weaving workers. The MSDs among 424 weavers with a response rate of 97.7%. The annual prevalence rate of work-related musculoskeletal disorders (WMSDs) among weavers was 76.3% [5]. The study found that the 12-month prevalence of MSDs was notably higher among handloom weavers compared to power loom weavers. Handloom weavers reported more frequent discomfort in the upper back (84–45%), lower back (82–50%), knee (60–35%), and shoulder (76–42%) [6]. Another study found that 50% of 660 traditional cloth weavers experienced low back pain after beginning weaving, and 44.1% had low back pain in the past year. Key factors linked to this pain included working over 8 hours daily, frequent bending, and job-related stress [7]. The high prevalence of MSDs highlights a need for targeted public health actions to improve workplace ergonomics and reduce physical strain for weavers.

The working-age population in informal labor groups is exposed to health risks, both from personal behaviors leading to chronic non-communicable diseases and health factors related to occupational activities that contribute to diseases and various injuries [8]. In particular, there are significant issues involving WMSDs, which can be considered the most common occupational diseases. In North East Thailand, there were 114,579 patients diagnosed with abnormal musculoskeletal and muscular systems associated with work, with an estimated incidence rate of approximately 189.37 per 100,000 population in 2018 [9]. The group engaged in traditional weaving, particularly those involved in silk weaving may encounter ergonomic issues from excessive frequency and force exerted during their work. Additionally, improper biomechanics, such as incorrect postures, can contribute to MSDs [10]. According to medical and health data from the Thailand Ministry of Public Health, weavers have been diagnosed with diseases related to the musculoskeletal and connective tissue groups, particularly those at risk due to high-intensity work in the upper limbs, including fingers and forearm muscles [1].

The profession of producing handwoven silk fabrics, particularly the production of Praewa silk, is considered unique to the people of Thai and Phu Thai ethnicities. It has gained recognition from both the public and private sectors at the national and international levels. This occupation is prevalent among communities in the northeastern region of Thailand, primarily in the provinces of Kalasin, Nakhon Phanom, Sakon Nakhon, and Mukdahan [11]. In addition, there are community enterprises involved in silk weaving in Kalasin province, such as Sam Chai, Somdet, Sahatsakhan Khao Wong, Ku Chang Nara, Na Khu, Namom, Nakhon in Nakhon Phanom province, and Nong Sung in Mukdahan province. The total membership in these groups in Kalasin is 2,310 people [12]. Another group involved in handwoven silk production is the Phu Thai Handwoven Silk Community in Phanna Nikhom, Sawang Daen Din, and Phu Nang National Park districts in Sakon Nakhon province, with 100 members [12]. MSDs are among the most common occupational diseases, typically affecting the lower back, neck, and both upper and lower

extremities [13]. However, few studies have been conducted on MSDs among Praewa silk weavers. The aim of this study was to determine the prevalence rate and associated occupational risk factors of MSDs among Praewa silk weavers in the Northeast region of Thailand.

Methods

Study participants

A cross-sectional study was conducted in the Northeast region of Thailand from November to December 2022. The study areas included Kalasin Province, Nakhon Phanom Province, Sakon Nakhon Province, and Mukdahan Province. The sample size was calculated using the prevalence of MSDs among handloom weavers from a previous study [2]. Based on the sample size calculation for Praewa silk weavers, the required number was 180 participants. To account for a 10% dropout rate, the adjusted sample size for this study was set at 198 participants. In actual data collection, the researcher successfully collected data from all 198 participants. Convenience sampling was used according to population proportions in each province to meet the required sample size of workers. All participants, aged 40 to 70 years, were recruited based on the inclusion criteria, which required at least one year of experience in weaving Praewa silk. All recruited participants were in good general health, available, and willing to participate in this study. Exclusion criteria were musculoskeletal deformities and a history of musculoskeletal diseases. Before data collection, informed consent was obtained from all participants.

Study instrument and variables

The study employed the Nordic Musculoskeletal Questionnaire (NMQ), consisting of three sections. The first section contained individual characteristics such as age, body mass index (BMI), and hand strength test [14]. The second section asked about work conditions, such as duration of work per day (hours), experience in weaving (years), and equipment usage. The final section included a self-report of MSDs adapted from the NMQ [15-17]. This tool evaluated the prevalence of work-related musculoskeletal symptoms, aches, pains, or discomfort experienced in the past 7 days and the past 12 months. The questions were as follows: “After you work, have you had any MSD complaints (illness, pain, inconvenience, and insensitivity) in any of the following body parts which interfered with your usual activities within the last 12 months? and in the past 7 days?” The score was categorized into two levels: 0 (no symptoms) and 1 (with symptoms). Pain intensity was evaluated using the Numerical Rating Scale (NRS) from 0 (no pain) to 10 (severe pain), with respondents indicating pain experienced from weaving tasks. The questionnaire was a standardized tool to determine the prevalence of MSDs among handloom weavers and is widely used worldwide [15-17]. The hand strength test evaluates the muscle strength of the hand and forearm by measuring each participant twice and recording the highest value obtained [18]. The hand strength test used a push-pull dynamometer to measure the force applied in pulling actions. Ergonomics was used to assess human strength, evaluate equipment, or ensure workplace safety. This measure serves as an indicator of hand and arm muscle strength and endurance [14]. The principal investigator, researchers, and three assistant researchers performed the measurements.

Ergonomic risk assessment

Ergonomic risk assessment in this study used two ergonomics observation methods. Rapid upper limb assessment (RULA) was used to evaluate the risk related to working posture for all participants [19,20]. The postural score increased when posture diverged from the neutral position. Posture selection for assessment was based on tasks that require the most difficult hand postures and work tasks or postures where the highest force load occurs. RULA evaluates four risk levels [21] including level 1: low score of 1–2 indicates that the job is acceptable, but it may pose ergonomic problems if performed repeatedly for an extended period; level 2: medium score of 3–4 indicates that the job should be considered for further study and continuous monitoring is required to redesign the job; level 3: high score of 5–6 indicates that the job is starting to become problematic; and level 4: a very high score of 7 or higher indicates that there are ergonomic issues that require immediate improvement [21,22].

The hand activity level (HAL) is a measure used to evaluate the amount and intensity of hand use in a task. It considers both the frequency of hand movements and the force exerted by the hands during a given activity. Force is represented by the normalized peak force (nPF) revised in the new 2018 version by the American Conference of Governmental Industrial Hygienists (ACGIH) to include activity level (AL=0.56) and threshold limit value (TLV=0.78) for hand activity. This tool was used to identify the level of hand activity on a scale of 0 to 10, where zero represents virtually no activity to a level of 10 (highest imaginable hand activity). The revised 2018 version is an effective tool for predicting the risk of MSD of the distal upper extremity disorders. When the AL or TLV is exceeded, risk control is recommended. If a task is above the AL but below the TLV, that indicates a slightly elevated risk of MSD, and control measures are recommended. If a task is assessed as above the TLV, then this indicates a significantly elevated risk of MSDs and appropriate control measures should be prioritized. Hand activity accounts for the combined influences of effort repetition and effort duration in a qualitative assessment [23,24]. High scores of RULA (more than 3) and HAL (more than 0.56) represent a high level of MSDs with indicated risk present (unacceptable).

Statistical analysis

Descriptive statistics were used to examine the characteristics of the weavers and the prevalence rates of MSDs. Associations between demographic characteristics, occupational potential risk factors, and reported MSDs were analyzed using multiple logistic regression, applying the adjusted odds ratio (AOR) with a 95% confidence interval. Data analysis was carried out using SPSS version 26.0 (IBM, Chicago, USA).

Results

Demographic characteristics of the participants

All participants were women with an average age of 55.76±7.66 years. Most participants were of normal weight with a BMI of 18.5 to 24.9 (53.03%), and the hand strength test results were mostly low (45.45%). Their average work experience was 34.44±8.79 years. The results revealed that the average amount of work was 7.13±1.10 hours per day, as presented in **Table 1**.

Table 1. Demographic characteristics of silk weaving workers (n=198)

Variables	Number	Percentage
Age (mean±SD, years)	55.76±7.66	
40–50	50	25.25
51–60	89	44.94
61–70	59	29.81
Body mass index (BMI)		
Normal weight	105	53.03
Overweight	93	46.97
Hand strength test		
Low	90	45.45
Quite low	57	28.78
Moderate	43	21.71
Good	8	4.06
Duration of work per day (mean±SD, hours)	7.13±1.10	
<5	6	3.03
5–6	51	25.76
7–8	135	68.18
>8	6	3.03
Experience in weaving (mean±SD, years)	34.44±8.79	
0–10	0	0
11–20	16	8.09
21–30	59	29.80
31–40	100	50.50
>41	23	11.61
Equipment usage		
Yes	45	22.73
No	153	77.27
Working accident at the wrist		
Yes	3	1.52

Variables	Number	Percentage
No	195	98.48
Frequency of musculoskeletal disorders (MSDs)		
Every day	140	70.71
1–3 times/week	57	28.79
1–5 times/month	1	0.50

SD: standard deviation

Prevalence of musculoskeletal disorders among participants

Participants reported the prevalence rates of MSD musculoskeletal symptoms in one or more body parts in the past 12 months and 7 days as 96.46% and 68.68%, respectively. The three body parts with the highest prevalence rates of symptoms were the wrist, fingers, and neck, as presented in **Table 2**.

Table 2. Prevalence of musculoskeletal disorders (MSDs) among participants (n=198)

Variables	Number	Percentage
Pain affected due to MSDs in the past 7 days		
Yes	136	68.68
No	62	31.32
Body parts affected due to MSDs in the past 7 days*		
Neck	121	61.11
Shoulder	87	43.94
Upper back	57	28.79
Lower back	125	63.13
Upper arm	43	21.72
Elbow	73	36.87
Lower arm	57	28.79
Wrist	134	67.67
Fingers	132	66.66
Thigh	46	23.23
Knee	46	23.23
Calf	39	19.70
Foot	46	23.23
Pain affected due to MSDs in the past 12 months		
Yes	191	96.46
No	7	3.54
Body parts affected due to MSDs in the past 12 months*		
Neck	127	64.14
Shoulder	77	38.89
Upper back	44	22.22
Lower back	122	61.62
Upper arm	48	24.24
Elbow	48	24.24
Lower arm	51	25.76
Wrist	178	89.90
Fingers	164	82.83
Thigh	58	29.29
Knee	53	26.77
Calf	51	25.76
Foot	60	30.30

*Percentage was calculated from the total respondents, indicating that each respondent may have one or more body parts affected due to MSDs

Ergonomic risk assessment

The results of the postural assessment were evaluated using RULA, with 89.39% of postures representing a very high risk (level 4), requiring investigation and implementation of changes, followed by the third level with 10.61%, which indicates high risk and calls for further investigation of changes to reduce or eliminate MSD risk (level 3). None of the respondents reported having no risk (level 1) or medium risk (level 2) (**Table 3**).

In terms of exposure to the level of hand activity, 91.42% of participants reported performing repetitive hand exertions above the TLV (>0.78), nearly 8.08% of subjects had daily exposures above the AL but below the TLV (0.56–0.78), and 0.50% of subjects had daily exposures above the AL (<0.56), as presented in **Table 3**.

Table 3. Ergonomic risk assessment among participants (n=198)

Ergonomic risk assessment	Number	Percentage
Rapid upper limb assessment (RULA)		
Score 1.00–2.00 (acceptable posture) - level 1	0	0.00
Score 3.00–4.00 (further investigation, change may be needed) - level 2	0	0.00
Score 5.00–6.00 (further investigation, change soon) - level 3	21	10.61
Score >7.00 (investigate and implement change) - level 4	177	89.39
Hand activity level (HAL)		
<0.56	1	0.50
0.56–0.78	16	8.08
>0.78	181	91.42

Occupational risk factors related to musculoskeletal disorders among Praewa silk weavers

The associated factors for musculoskeletal disorders (MSDs) were identified as follows: individuals aged 51–60 years were 0.13 times less likely to develop MSDs compared to those aged 40–50 years (AOR=0.13; 95%CI: 0.15–1.09). Participants with low hand strength levels were 2.09 times more likely to experience MSDs than those with good hand strength (AOR=2.09; 95%CI: 0.44–11.05). Similarly, individuals with quite low hand strength levels were 2.49 times more likely to report MSDs than those with good hand strength (AOR=2.49; 95%CI: 0.29–21.15). Regarding years of weaving experience, those who experienced weaving for 21–30 years were 1.07 times more likely to have MSDs than those who experienced weaving for 11–20 years (AOR=1.07; 95%CI: 0.20–5.64). Participants with 31–40 years of experience were 2.63 times more likely to have MSDs than those with 11–20 years of experience (AOR=2.63; 95%CI: 0.49–13.91). Additionally, individuals with more than 41 years of experience were 1.13 times more likely to report MSDs compared to those with 11–20 years of experience (AOR=1.13; 95%CI: 1.08–1.19). In terms of ergonomic risk assessment, participants with a RULA score of level 4 were 3.62 times more likely to experience MSDs than those with a RULA score of level 3 (AOR=3.62; 95%CI: 0.66–19.96). Furthermore, those with a HAL score greater than 0.78 were 0.63 times less likely to have MSDs than those with a HAL score below 0.56 (AOR=0.63; 95%CI: 0.80–0.98), as summarized in **Table 4**.

Table 4. Associated risk factors for musculoskeletal disorders (MSDs) among silk weavers (n=198)

Variables	MSDs		Crude odds ratio (95%CI)	Adjusted odds ratio (95%CI)
	Yes (%) (n=191)	No (%) (n=7)		
Age (years)				
40–50	50 (26.18%)	0 (0.00%)	ref	ref
51–60	83 (43.46%)	6 (85.71%)	0.14 (0.17–1.11)	0.13 (0.15–1.09)*
61–70	58 (30.36%)	1 (14.29%)	2.67 (0.33–21.71)	2.75 (0.32–23.33)
Body mass index (BMI)				
Normal weight	101 (52.88%)	4 (57.15%)	ref	ref
Overweight	90 (47.12%)	3 (42.85%)	1.18 (0.27–5.14)	1.19 (0.25–5.34)
Hand strength test				
Low	88 (46.07%)	2 (28.57%)	2.04 (0.41–10.27)	2.09 (0.44–11.05)*
Quite low	56 (29.32%)	1 (14.29%)	2.42 (0.30–19.70)	2.49 (0.29–21.15)*
Moderate	40 (20.94%)	3 (42.85%)	0.37 (0.09–1.59)	0.35 (0.08–1.64)
Good	7 (3.67%)	1 (14.29%)	ref	ref
Duration of work per day (hours)				
<5	6 (3.14%)	0 (0.00%)	ref	ref
5–6	50 (26.18%)	1 (14.29%)	2.08 (0.26–16.88)	2.13 (0.25–18.11)
7–8	129 (67.54%)	6 (85.71%)	0.36 (0.44–2.90)	0.35 (0.41–2.94)
>8	6 (3.14%)	0 (0.00%)	0.96 (0.94–0.99)	1.04 (1.01–1.07)
Experience in weaving (years)				
11–20	13 (6.81%)	3 (42.85%)	ref	ref
21–30	57 (29.84%)	2 (28.57%)	1.06 (0.21–5.32)	1.07 (0.20–5.64)*
31–40	98 (51.31%)	1 (14.29%)	2.55 (0.51–12.84)	2.63 (0.49–13.91)**
>41	23 (12.04%)	1 (14.29%)	0.96 (0.93–0.99)	1.13 (1.08–1.19)*
Equipment usage				
Yes	42 (21.99%)	3 (42.85%)	ref	ref
No	149 (78.01%)	4 (57.15%)	2.55 (0.59–10.98)	2.66 (0.57–12.36)

Variables	MSDs		Crude odds ratio (95%CI)	Adjusted odds ratio (95%CI)
	Yes (%) (n=191)	No (%) (n=7)		
Rapid upper limb assessment (RULA)				
Level 3	19 (9.95%)	2 (28.57%)	ref	ref
Level 4	172 (90.05%)	5 (71.43%)	3.37 (0.70–16.31)	3.62 (0.66–19.96)**
Hand activity level (HAL)				
<0.56	1 (0.52%)	0 (0.00%)	ref	ref
0.56–0.78	15 (7.85%)	1 (14.29%)	0.96 (0.93–0.99)	0.56 (0.70–1.10)
>0.78	175 (91.63%)	6 (85.71%)	1.04 (1.01–1.07)	0.63 (0.80–0.98)*

*Statistically significant at $p<0.05$
**Statistically significant at $p<0.01$

Discussion

The prevalence of MSDs among Praewa silk weavers was found to be 68.68%, with workers who experienced acute symptoms and pain due to MSDs in the past 7 days. The highest prevalence was found mostly in the wrist, fingers, and lower back. Pain affecting workers due to MSDs in the past 12 months was reported at 96.46%, indicating chronic prevalence. The highest pain was found in the wrist, fingers, and neck. The Praewa silk weavers experienced the highest prevalence of symptoms in the wrist area, which can be attributed to the nature of the work, where individual silk threads are meticulously woven one at a time. It takes approximately 3–5 months to complete one piece of silk fabric. Among manual handloom weavers in Thailand, musculoskeletal symptoms are highly prevalent, with the highest percentages being 91.43%, 85.71%, and 60.00% for the shoulder, lower back, and wrist, respectively [2]. A previous study found that discomfort occurs in weaving workers [25]. One in three individuals in the sample group experiences discomfort in the upper limbs. The cumulative incidents in the wrist and hand are more than 70%. There is an observed prevalence of musculoskeletal and muscular system issues reported among silk weavers, particularly those related to WMSD [25,26]. Also, a previous study found that there was a significant correlation between MSD pains and sitting time [27], which prevents workers from performing their tasks effectively [28]. The most affected areas are the shoulder, lower back, and wrist. Various workplace factors contribute to these issues, such as repetitive and static work, stress, and tension, which are correlated with the occurrence of pain and discomfort [29].

The ergonomic risk assessment for the posture of Praewa silk weavers, evaluated using the RULA, revealed the highest risk level 4, indicating that the work poses significant issues that should be addressed promptly. The main issue is maintaining the same working posture for extended periods, particularly in the wrist and fingers, where repetitive motions over long durations contribute to the risk. The HAL assessment also showed that most weavers are at a very high-risk level, requiring immediate corrective action. Regarding the TVL assessment of the Praewa silk weaving process, it was found that the task involves using hands to pull cloth device silk thread individually in a repetitive manner. The posture involves wrist rotations to insert the silk threads into the fabric pattern, with prolonged hours of work per day. Additionally, there is no equipment available to help reduce the physical strain from pulling or holding the silk threads. The incorrect posture, such as twisting the wrist and maintaining finger tension for long periods, exacerbates the risk. This finding is consistent with the study, which examined the prevalence of MSDs in relation to work postures [30]. Therefore, this weaving process requires significant ergonomic adjustments, including the design of appropriate tools and posture modifications to prevent and reduce MSDs that may develop.

This study found a strong link between working posture and MSDs among weavers, with postures assessed at RULA level. Factors such as work experience, working hours, and posture contributed significantly to MSD symptoms. The findings highlight that weaving postures are central to developing musculoskeletal issues, suggesting that ergonomic interventions and posture improvements could help reduce MSD risk among weavers. This is attributed to the fact that factors influencing Praewa silk weaving are highly dependent on experience, particularly in crafting intricate patterns that demand the specialized skills and expertise of Praewa silk weavers. A study examining the prevalence of WMSDs among silk weavers revealed that approximately 46% of workers experienced MSDs over the past 12 months, with 76.1% of these individuals

reporting symptoms specifically related to MSDs [31]. Additionally, the number of working hours was statistically significantly associated with elbow injuries [32].

The strength to study underscores a strong connection between ergonomic practices and MSDs in the Praewa silk weaving, shedding light on an area often overlooked in ergonomic research. Findings related to the role of posture, experience, and working hours in MSD risk offer valuable data to inform targeted safety and ergonomic interventions for weaving tasks. The limited sample size may affect the study's generalizability across all regions involved in Praewa silk weaving, as variations in regional weaving techniques and cultural practices may influence the relevance of findings.

Conclusion

The study on the high prevalence of MSDs among Praewa silk weavers found that MSDs are associated with age, hand strength test results at low level and quite low level, experience in weaving for 31–40 years and more than 41 years, RULA level 4, and HAL. The study suggests that measures should be taken to prevent and control MSDs, such as adjusting workstations, designing appropriate equipment, and providing a safe working environment for weavers. Praewa silk weaving is a manual weaving process, requiring the pulling of each silk thread individually. Additionally, ergonomically designed equipment is essential in this process to reduce the risk of MSDs and prevent injuries. This study provides valuable insights for occupational health and safety interventions in the Praewa silk weaving industry and suggests that similar interventions may be beneficial in other industries or occupations that involve similar ergonomic risk factors.

Ethics approval

The study was approved by the Human Research Ethics Committee of Thammasat University (Science), No. 66EN108, and informed consent was obtained from all participants.

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Competing interests

All the authors declare that there are no conflicts of interest.

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Underlying data

The data that support the findings of this study are available on request from the corresponding author.

Declaration of artificial intelligence use

We hereby confirm that no artificial intelligence (AI) tools or methodologies were utilized at any stage of this study, including during data collection, analysis, visualization, or manuscript preparation. All work presented in this study was conducted manually by the authors without the assistance of AI-based tools or systems.

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