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Integrating Ergonomic Risk Assessment with the Hierarchy of Controls Among Informal Sewing Workers in Rural Thailand

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Highlights

This study provides comprehensive evidence on ergonomic and mental workload risks among informal sewing workers in Thailand, demonstrating a high prevalence of hazardous postures, repetitive tasks, and prolonged static work that contribute to work-related musculoskeletal disorders (WMSDs). Using validated tools (RULA, NASA-TLX, and NMQ), the findings show that physical demand and performance pressure are key contributors to overall workload, while lower educational attainment and younger working age are associated with higher ergonomic risk exposure and WMSD prevalence. By applying the Hierarchy of Ergonomic Controls, the study highlights that elimination and substitution strategies are the most effective preventive measures in informal work settings, offering practical, low-cost guidance to reduce occupational health risks and inform policy and community-based ergonomic interventions.

What are the main findings?

The study found that informal sewing workers experience extensive ergonomic risk exposure, particularly prolonged sitting, repetitive movements, and awkward neck and trunk postures, resulting in a high prevalence of work-related musculoskeletal disorders, especially in the neck, shoulders, and back. Physical workload and performance demands were identified as the primary contributors to overall workload, with physical demand showing a significant association with perceived workload. Younger workers and those with lower educational attainment exhibited higher exposure to ergonomic risks and greater WMSD prevalence. Application of the Hierarchy of Ergonomic Controls demonstrated that elimination and substitution strategies were the most effective approaches for reducing ergonomic risks in informal sewing work, while administrative controls and personal protective equipment provided limited protection.

What are the implications of the main findings?

The findings indicate an urgent need to address ergonomic hazards and workload pressures among informal sewing workers, a population largely excluded from formal occupational health protections. Interventions should prioritize higher-order ergonomic controls, particularly elimination and substitution strategies, as these offer the greatest potential to reduce work-related musculoskeletal disorders in resource-limited settings. The strong association between lower educational attainment and higher ergonomic risk underscores the importance of targeted ergonomic education and capacity-building programs. Additionally, the contribution of physical and performance-related workload highlights the need to integrate mental workload management into ergonomic interventions. At the policy level, the results support the development of inclusive occupational

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health policies and community-based ergonomic programs to reduce health inequities and improve the sustainability of informal work.

Abstract

Background: Informal sewing workers are widely exposed to ergonomic and workload-related risks but remain largely excluded from formal occupational health protection, particularly in low- and middle-income countries. This study aimed to assess ergonomic risk factors, mental workload, and work-related musculoskeletal disorders (WMSDs) among informal sewing workers and to develop preventive guidelines based on the Hierarchy of Ergonomic Controls (HEC). Methods: A mixed-methods study was conducted among 150 informal sewing workers in Ubon Ratchathani Province, Thailand. Quantitative data were collected using a structured questionnaire, the Rapid Upper Limb Assessment (RULA), the Nordic Musculoskeletal Questionnaire (NMQ), and the NASA Task Load Index (NASA-TLX). Associations between sociodemographic characteristics, ergonomic risks, and WMSDs were analyzed using chi-square tests and correlation analysis. Qualitative data were obtained through a focus group discussion with key stakeholders to develop ergonomic control strategies guided by the HEC framework. Results: The majority of participants were female and middle-aged, with widespread exposure to high-risk ergonomic conditions, including prolonged sitting, repetitive tasks, and awkward postures. A high prevalence of WMSDs was observed, particularly in the neck, shoulders, and back. Younger workers and those with lower educational attainment experienced significantly higher ergonomic risk exposure and WMSD prevalence. NASA-TLX results indicated that physical demand and performance pressure were the main contributors to overall workload. Application of the HEC framework showed that elimination and substitution controls were the most effective strategies for reducing ergonomic risks, followed by engineering controls, while administrative measures and personal protective equipment were less effective. Conclusions: Informal sewing workers face substantial ergonomic and mental workload risks that contribute to a high burden of WMSDs. Prioritizing higher-order ergonomic controls, integrating workload management, and implementing community-based ergonomic interventions are essential to improving occupational health and reducing inequities among informal workers.

Keywords: informal workers; sewing workers; ergonomics; work-related musculoskeletal disorders; mental workload; NASA-TLX; Rapid Upper Limb Assessment; hierarchy of ergonomic controls; occupational health

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1. Introduction

Informal workers, defined as individuals without formal employment contracts, represent a significant global workforce. An estimated 2 billion informal workers are exposed to economic, social, and health risks, particularly in low- and middle-income countries, with 88% of them residing in Asia [1,2]. These workers frequently operate in hazardous environments, often lacking access to occupational health services. Ergonomic risks are among the most prevalent hazards in this group. In India, 85% of informal workers are exposed to ergonomic risks [3]. Studies in Indonesia, Nigeria, and India have reported high rates of musculoskeletal disorders (MSDs) among sewing workers, primarily in the lower back, neck, shoulders, and wrists [4–7].

Musculoskeletal disorders in sewing workers are primarily associated with awkward postures, poor workstation design, prolonged static work, and repetitive movements, particularly affecting the neck and upper limbs [8]. Ergonomic risk factors include excessive force, repetitive tasks, awkward joint angles, hand-arm vibrations, and sustained kneeling or squatting [9]. Various validated tools such as the Ovako Working Posture Analysis System (OWAS), Rapid Upper Limb Assessment (RULA), and Rapid Entire Body Assessment (REBA) have been widely applied for ergonomic risk assessments in manufacturing and informal sectors [10].

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Workload can be categorized into physical and mental components. According to ergonomic models, workload has three levels: optimal, overcapacity, and undercapacity [11]. While physical workload has been extensively studied using tools like OWAS, RULA, and REBA, mental workload is assessed using the NASA Task Load Index (NASA-TLX). Developed by NASA Ames Research Center, the NASA-TLX evaluates six subscales: mental demand, physical demand, temporal demand, performance, effort, and frustration. These are combined to produce a Weighted Workload (WWL) score [12,13]. Studies in textile industries have shown that sewing machine operators often experience high mental workloads, with performance and effort being the most influential dimensions [14]. Work-related musculoskeletal disorders (WMSDs) range in severity and are influenced by physical tasks and environmental conditions. They are often aggravated by poorly designed workstations, mismatch between job demands and worker capabilities, and cumulative mental workload [15]. The Nordic Musculoskeletal Questionnaire (NMQ) is commonly used for screening musculoskeletal symptoms due to its standardization, global applicability, cost-effectiveness, and ease of use. However, its use in non-English-speaking contexts requires careful translation and validation. Key regions for ergonomic assessment include the lumbar spine, cervical spine, and shoulders [16].

To address ergonomic challenges, the Hierarchy of Controls is widely used to guide interventions. This framework ranks interventions from most to least effective: elimination, substitution, engineering controls, administrative controls, and personal protective equipment (PPE) [17]. Applying this model helps ensure that ergonomic solutions are both effective and sustainable. Its goal is to minimize the incidence of WMSDs while enhancing productivity by aligning task design with workers' physiological capabilities and limitations [18–20]. Although registered enterprises may implement formal ergonomic controls, informal workers remain underserved. Prior research has shown that both physical and mental workloads contribute significantly to WMSDs in informal settings [14]. Therefore, this study aimed to assess ergonomic and mental workload risks among informal sewing workers in Ubon Ratchathani, Thailand, and to develop preventive guidelines based on the hierarchy of controls. RULA was used to assess the physical demands related to repetitive upper-limb tasks, with a focus on evaluating muscle effort, fatigue, and posture-related risks.

2. Materials and Methods

2.1. Study Design and Sampling

A mixed-methods design was employed to assess ergonomic risks among informal sewing workers in Ubon Ratchathani Province, Thailand, between October and December 2022. The study was conducted in two phases: 1) a quantitative survey and ergonomic risk assessment, and 2) a qualitative focus group discussion (FGD) aimed at developing ergonomic control guidelines.

In the quantitative phase, three instruments were applied: 1) a structured questionnaire to capture sociodemographic and work-related characteristics, 2) the Rapid Upper Limb Assessment (RULA) to evaluate ergonomic risk, and 3) the NASA Task Load Index (NASA-TLX) to assess mental workload. A multi-stage sampling procedure was used to enhance representativeness and minimize selection bias. The process comprised four steps: 1) Regional stratification – Informal sewing worker populations were stratified into three regions (Northeast, South, and Central) in proportional ratios of 8:7:5, respectively. 2) Province selection – Provinces within each stratum were selected using simple random sampling (eight from the Northeast, seven from the South, and three from the Central region). 3) Target province – Ubon Ratchathani Province was randomly selected from the Northeast region.4) District selection – Muang Sam Sip District was randomly chosen from the 25 districts in Ubon Ratchathani. Following this, quota sampling was used to recruit 150 informal sewing workers, with 50 participants each from Yang Sak Krapho Lum (YL), Phai Yai (PY), and Yang Yo Phap (YP).

In the qualitative phase, one FGD was conducted to develop practical ergonomic control guidelines based on the Hierarchy of Controls. A total of 16 stakeholders participated: six community leaders, six representatives of sewing groups, and four health promotion officers.

2.2. Study Instruments and Data Collection

2.2.1. Study Instruments and Data Collection

Developed by the research team to capture sociodemographic data (e.g., age, gender, education), occupational history (e.g., prolonged sitting, bending, repetitive tasks, workload), and working conditions. Content validity was assessed by three occupational health experts, and a pilot test with 20 informal sewing workers outside the study area ensured clarity and feasibility. The questionnaire was revised based on feedback prior to full implementation.

2.2.2. Rapid Upper Limb Assessment (RULA)

RULA was applied to evaluate ergonomic risks associated with sewing-related postures. Four key tasks were assessed: fabric preparation, cutting, machine sewing (approximately 4 hours/day), and product inspection/packaging. Observations were supplemented with video and photographic recordings. RULA scores (1–7) were categorized into four action levels, ranging from acceptable posture to requiring immediate corrective action [21,22]. Four core sewing-related tasks were analyzed: 1) fabric preparation, 2) cutting, 3) machine sewing (approximately 4 hours/day), and 4) product inspection and packaging [23] (Figure. 1 and Table 1).

Figure 1. Analysis of the Sewing process.

Table 1. RULA score and level of WMSD risk.

Score	Level of WMSD Risk
1-2	Acceptable working posture if not maintained or repeated for long periods.
3-4	Further investigation is needed. Posture change may be required.
5-6	Investigate and implement posture changes soon to avoid further exposure to WMSD risk.
7	Requires immediate attention and changes in posture.

2.2.3. NASA Task Load Index (NASA-TLX)

Mental workload was assessed using the NASA-TLX, a multidimensional tool evaluating six subscales: mental demand, physical demand, temporal demand, performance, effort, and frustration [12,13,24]. The procedure involved three steps:

1. Weighting: Participants selected the more demanding factor in 15 paired comparisons.
2. Rating; Each subscale was rated on a 21-point scale (0 = very low, 20 = very high).
3. Scoring; Each rating was multiplied by its respective weight, and the Weighted Workload (WWL) was calculated as the sum of these products.
4. The TLX average score; was computed as WWL/15 and categorized into five workload levels: very low (0–20), Low (21–40), Medium (41–59), High (60–79), or very high (80–100) [25].

2.2.2. Qualitative Instruments

A semi-structured FGD guide was developed using the Hierarchy of Controls framework. The guide addressed elimination of hazardous tasks, substitution, engineering controls, administrative measures, and personal protective equipment (PPE) [16].

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Qualitative data were collected on-site at participants' workplaces during regular working hours to ensure ecological validity. Trained ergonomics researchers conducted observations for RULA scoring and administered the NASA-TLX immediately after sewing tasks to capture real-time perceptions of workload. Following the quantitative survey, a single FGD was conducted with 16 stakeholders (six community leaders, six sewing group representatives, and four health promotion officers). The session lasted approximately two hours and was facilitated by two trained moderators. Discussions were audio-recorded and transcribed verbatim, with participants' consent. Data were later analyzed to identify feasible ergonomic interventions tailored to informal sewing contexts.

2.3. Data Analysis

Quantitative data from the questionnaires, RULA assessments, and NASA-TLX scores were entered into SPSS version 19 for statistical analysis. Descriptive statistics were used to summarize participants' sociodemographic characteristics, ergonomic risk levels, and workload scores. Inferential analyses included Chi-square and Fisher's exact tests to examine associations between demographic/work characteristics and the prevalence of work-related musculoskeletal disorders (WMSDs). Pearson's correlation analysis was applied to assess relationships between ergonomic risk levels (RULA scores) and mental workload (NASA-TLX). All statistical tests were two-tailed, and a p value of < 0.05 was considered statistically significant.

Qualitative data from the focus group discussions were transcribed verbatim in Thai, reviewed independently by two researchers, and analyzed thematically using an inductive approach. Emergent themes were mapped to the Hierarchy of Controls framework (elimination, substitution, engineering, administrative, and PPE). To enhance credibility, data triangulation was conducted across community leaders, sewing group representatives, and health promotion officers, with discrepancies resolved through consensus.

2.4. Ethical Considerations

The study protocol was approved by Ubon Ratchathani Rajabhat University Ethics Committee (Reference No. HE652033-031/2565). Prior to data collection, participants were informed about the study objectives, procedures, potential risks, and benefits. Written informed consent was obtained from all participants before participation.

3. Results

3.1. Participant Characteristics and Ergonomic Risk Factors

Table 2 presents the sociodemographic characteristics and work-related risk profiles of informal workers included in the study (N = 150). The sample was predominantly female, with 141 participants (94.0%), while males accounted for only 6.0% (n = 9). Regarding age distribution, nearly half of the participants were aged 50–60 years (48.0%, n = 72), followed by those aged < 50 years (34.7%, n = 52) and > 60 years (17.3%, n = 26). The mean age of the participants was 53.41 years (SD = 7.78), with an age range spanning from 31 to 76 years, indicating a predominantly middle-aged to older workforce. In terms of educational attainment, the majority of participants had completed more than high school education (62.0%, n = 93), while 38.0% (n = 57) had an education level below high school. With respect to income, most participants reported earning more than 5,000 baht per month (85.3%, n = 128), whereas 14.7% (n = 22) reported a monthly income below this threshold. The assessment of high-risk work characteristics revealed widespread exposure to ergonomic risk factors. Prolonged sitting for more than two hours was reported by 86.7% of participants (n = 130). Almost all workers reported head bending or lifting (98.0%, n = 147), twisting or tilting the body (93.3%, n = 140), and repetitive tasks (93.3%, n = 140). Additionally, forward bending was reported by 91.3% (n = 137), and lifting heavy objects by 71.3% (n = 107). A substantial proportion of participants indicated working hurriedly (80.7%, n = 121), while excessive workload was reported by 28.7% (n = 43). Notably, nearly all

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participants experienced uncertain income (98.0%, n = 147), highlighting economic instability within this informal workforce. (Table 2).

Table 2. The participant characteristics of informal workers (N=150).

Characteristics Variables	Categories	N	Percentage
Gender	Male	9	6.0
	Female	141	94.0
Age group	< 50 years	52	34.7
Mean=53.41, SD=7.780, Max=76,	50-60 years	72	48.0
Min=31	> 60 years	26	17.3
Education	≤ high school	57	38.0
	> high school	93	62.0
Income	<5,000 baht per mont (about $152)	22	14.7
	≥ 5,000 baht per mont	128	85.3
High-risk work	Sitting >2 hours	130	86.7
	Head bending/lifting	147	98.0
	Forward bending	137	91.3
	Twisting/tilting body	140	93.3
	Repetitive tasks	140	93.3
	Lifting heavy objects	107	71.3
	Working hurriedly	121	80.7
	Complex tasks	11	7.3
	Excessive workload	43	28.7
	Uncertain income	147	98.0

Table 3 presents the associations between sociodemographic characteristics and specific ergonomic risk factors among the study participants (N = 150). Overall, several ergonomic risk exposures showed statistically significant associations with age and educational level, while gender differences were less consistently observed.

Regarding gender, most ergonomic risk factors did not differ significantly between males and females. However, lifting heavy objects was reported exclusively among female participants (75.9%), yielding a statistically significant association ($\chi^2 = 23.83$, $p < 0.001$). In addition, working hurriedly ($\chi^2 = 8.06$, $p = 0.005$) and engagement in complex tasks ($\chi^2 = 9.52$, $p = 0.002$) were significantly associated with gender, indicating a higher prevalence among female workers.

In terms of age group, participants aged < 60 years reported significantly higher exposure to certain ergonomic risks compared with those aged ≥ 60 years. Specifically, sitting for more than 2 hours was significantly associated with age ($\chi^2 = 6.51$, $p = 0.025$), as was forward bending ($\chi^2 = 4.02$, $p = 0.045$). Other ergonomic factors, including head bending/lifting, twisting or tilting the body, repetitive tasks, lifting heavy objects, working hurriedly, complex tasks, and excessive workload, did not demonstrate statistically significant age-related differences.

With respect to educational level, several ergonomic risk factors were significantly more prevalent among participants with lower than high school education. These included sitting for more than 2 hours ($\chi^2 = 14.14$, $p < 0.001$), forward bending ($\chi^2 = 8.72$, $p = 0.003$), twisting or tilting the body ($\chi^2 = 6.57$, $p = 0.010$), repetitive tasks ($\chi^2 = 4.66$, $p = 0.031$), lifting heavy objects ($\chi^2 = 3.95$, $p = 0.047$), and complex tasks ($\chi^2 = 7.28$, $p = 0.007$). No statistically significant associations were observed between educational level and head bending/lifting, working hurriedly, excessive workload, or uncertain income. (Table 3).

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Table 3. Sociodemographic characteristics and specific ergonomic risk factors (N=150).

Working Characteristics	Gender			Age Group			Education		
	Male	Female	Chi-square (*p*)	< 60 years	≥ 60 years	Chi-square (*p*)	> high school	≤ high school	Chi-square (*p*)
	N (%)	N (%)		N (%)	N (%)		N (%)	N (%)	
1) Sitting >2 hours	9 (6.9)	121 (93.1)	1.47 (.608)	104 (80.0)	26 (20.0)	6.51 (.025)*	57 (43.8)	73 (56.2)	14.14 (.000)*
2) Head bending/lifting	9 (6.1)	138 (93.9)	.195 (.658)	121 (82.3)	26 (17.7)	.863 (.353)	54 (36.7)	93 (63.3)	4.995 (.053)
3) Forward bending	9 (6.6)	128 (93.4)	.909 (.341)	111 (81.0)	26 (19.0)	4.015 (.045)*	57 (41.6)	80 (58.4)	8.724 (.003)*
4) Twisting/tilting body	9 (6.4)	131 (93.6)	.684 (.408)	114 (81.4)	26 (18.6)	3.022 (.082)	57 (40.7)	83 (59.3)	6.567 (.010)*
5) Repetitive tasks	9 (6.4)	131 (93.6)	.684 (.408)	114 (81.4)	26 (18.6)	3.022 (.082)	50 (35.7)	90 (64.3)	4.657 (.031)*
6) Lifting heavy objects	0 (0.0)	107 (75.9)	23.825 (.000)*	92 (86.0)	15 (14.0)	.451 (.502)	46 (43.0)	61 (57.0)	3.946 (.047)
7) Working hurriedly	9 (7.9)	105 (92.1)	8.055 (.005)*	92 (80.7)	22 (19.3)	2.846 (.092)	31 (27.2)	83 (72.8)	1.611 (.204)
8) Complex tasks	3 (27.3)	8 (72.7)	9.524 (.002)*	11 (100.0)	0 (0.0)	3.348 (.067)	0 (0.07)	11 (100)	7.275 (.007)*
9) Excessive workload	3 (7.0)	40 (93.0)	.102 (.749)	32 (74.4)	11 (25.6)	.451 (.502)	19 (44.2)	24 (55.8)	.979 (.322)
10) Uncertain income	9 (6.1)	138 (93.9)	.195 (.658)	114 (77.6)	33 (22.4)	.863 (.353)	57 (38.8)	90 (61.2)	1.876 (.171)

* $p < 0.05$.

3.2. Prevalence of Work-Related Musculoskeletal Disorders (WMSDs)

Table 4 summarizes the associations between sociodemographic characteristics and the prevalence of work-related musculoskeletal disorders (WMSDs) among participants (N = 150). The findings indicate that age group and educational level were consistently associated with WMSDs in multiple body regions, whereas gender differences were significant only for selected anatomical sites.With respect to gender, most WMSDs did not differ significantly between male and female participants. However, statistically significant gender differences were observed for hand/wrist disorders ($\chi^2 = 9.54$, p = 0.002), knee disorders ($\chi^2 = 5.70$, p = 0.017), and calf disorders ($\chi^2 = 5.39$, p = 0.020), with a higher prevalence reported among female participants. No significant gender-based differences were found for neck, shoulder, upper back, lower back, upper arm, elbow, lower arm, hip, or foot disorders. Regarding age group, participants aged < 60 years demonstrated a significantly higher prevalence of WMSDs in several body regions compared with those aged ≥ 60 years. Significant associations were identified for neck pain ($\chi^2 = 20.33$, p < 0.001), shoulder pain ($\chi^2 = 7.64$, p = 0.006), upper back pain ($\chi^2 = 11.94$, p = 0.001), and lower back pain ($\chi^2 = 6.38$, p = 0.012). Other regions, including the upper arm, elbow, lower arm, hand/wrist, hip, knee, calf, and foot, did not show statistically significant differences by age group. In terms of educational level, participants with lower than high school education exhibited a significantly higher prevalence of WMSDs across multiple anatomical sites. Significant associations were observed for disorders affecting the neck ($\chi^2 = 9.60$, p = 0.002), shoulder ($\chi^2 = 4.87$, p = 0.027), upper back ($\chi^2 = 9.03$, p = 0.003), lower back ($\chi^2 = 5.78$, p = 0.016), hand/wrist ($\chi^2 = 13.75$, p < 0.001), hip ($\chi^2 = 19.92$, p < 0.001), knee ($\chi^2 = 7.21$, p = 0.007), and calf (p = 0.385, not significant). No significant educational differences were detected for upper arm, elbow, lower arm, or foot disorders. (Table 4.)

Table 4. Sociodemographic characteristics and the prevalence of WMSDs (N=150).

Working Characteristics	Gender			Age Group			Education		
	Male	Female	Chi-square	< 60 years	≥ 60 years	Chi-square	> high school	< high school	Chi-square
	N (%)	N (%)	(*p*)	N (%)	N (%)	(*p*)	N (%)	N (%)	(*p*)
Neck	4 (3.5)	109 (96.5)	4.916 (.27)*	98 (86.7)	15 (13.3)	20.326 (.000)*	35 (31.0)	78 (69.0)	9.600 (.002)*
Shoulder	5 (4.5)	105 (95.5)	1.547 (.214)	92 (83.6)	18 (16.4)	7.637 (.006)*	36 (32.7)	74 (67.3)	4.868 (.027)*
Upper back	7 (7.6)	94 (92.4)	.475 (.491)	87 (86.1)	14 (13.9)	11.943 (.001)*	30 (29.7)	71 (70.3)	9.034 (.003)*
Lower back	7 (77.8)	85 (60.3)	1.092 (.296)	78 (84.8)	14 (15.2)	6.379 (.012)*	28 (30.4)	64 (69.6)	5.780 (.016)*
Upper arm	6 (6.8)	82 (93.2)	.253 (.615)	73 (83.0)	15 (17.0)	3.046 (.081)	28 (31.8)	60 (68.2)	3.453 (.063)
Elbow	2 (6.3)	30 (93.8)	.003 (.955)	26 (81.3)	6 (18.8)	.180 (.672)	9 (28.1)	23 (71.9)	1.554 (.213)
Lower arm	4 (10.0)	36 (90.0)	1.511 (.219)	35 (87.5)	5 (12.5)	2.952 (.086)	13 (32.5)	27 (67.5)	.767 (.381)
Hand/Wrist	8 (13.3)	52 (86.7)	9.535 (.002)*	51 (85.0)	9 (15.0)	2.855 (.091)	12 (20.0)	48 (80.0)	13.752 (.000)*
Hip	6 (7.8)	71 (92.2)	.901 (.342)	65 (84.4)	12 (15.6)	3.795 (.051)	16 (20.8)	61 (79.2)	19.915 (.000)*
Knee	9 (9.6)	85 (90.4)	5.704 (.017)*	77 (81.9)	17 (18.1)	2.249 (.134)	28 (29.8)	66 (70.2)	7.208 (.007)*
Calf	9 (9.4)	87 (90.6)	5.386 (.020)*	74 (77.1)	22 (22.9)	.131 (.718)	34 (35.4)	62 (64.6)	.755 (.385)
Foot	6 (6.4)	88 (93.6)	.065 (.789)	76 (80.9)	18 (19.1)	1.193 (.275)	33 (35.1)	61 (64.9)	.895 (.344)

* $p < 0.05$.

3.2. Mental Workload Assessment (NASA-TLX)

Table 5 presents the summary of perceived workload as assessed using the NASA Task Load Index (NASA-TLX) among informal sewing workers (n = 150). The analysis includes weighted workload levels (WWL), risk categorization, mean scores with standard deviations, and correlation coefficients. Overall, the performance dimension demonstrated the highest workload burden, with a WWL score of 77.90, corresponding to a high risk level. This indicates that workers perceived substantial demands related to task performance requirements. Despite its high workload classification, the performance subscale did not show a statistically significant correlation (r = 0.081, p = 0.325). The physical demand dimension exhibited a medium risk level, with a WWL of 51.43 and a mean score of 46.44 ± 27.36. Physical demand was significantly correlated with overall workload outcomes (r = 0.312, p < 0.001), suggesting that physical strain constitutes a key contributor to perceived workload among informal sewing workers. In contrast, mental demand, temporal demand, and effort were classified as low risk levels, with WWL values of 37.97, 32.07, and 36.53, respectively. Among these, mental demand demonstrated a statistically significant but weak positive correlation (r = 0.171, p = 0.037), while temporal demand (r = −0.132, p = 0.108) and effort (r = −0.151, p = 0.065) did not reach statistical significance. The frustration subscale recorded the lowest workload contribution, with a WWL of 4.63 and a very low risk level. The mean frustration score was 4.90 ± 10.00, and no significant correlation was observed (r = 0.024, p = 0.768). (Table 5).

Table 5. NASA TLX Summary for informal Sewing workers (n=150).

Subscale	Weight	Rating	WWL	Risk level	Mean± SD	Coefficients (r)	*p*-value
Mental	2.60	14.37	37.97	Low	32.18±21.21	0.171	.037*
Physical	3.47	15.90	51.43	Medium	46.44±27.36	0.312	<.001*
Temporal	2.43	13.50	32.07	Low	31.21±16.35	- 0.132	.108

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Performance	4.23	18.37	77.90	High	73.80±21.78	0.081	.325
Effort	2.27	16.67	36.53	Low	41.44±21.55	- 0.151	.065
Frustration	0.40	7.63	4.63	Very Low	4.90±10.00	0.024	.768

* $p < 0.05$.

3.5. Hierarchy of Ergonomic Controls (HEC)

Table 6 summarizes the implementation of the Hierarchy of Ergonomic Controls (HEC) applied to prevent and mitigate work-related musculoskeletal disorders (WMSDs) among informal sewing workers. The findings illustrate a graded approach to ergonomic risk reduction, with varying levels of effectiveness across control strategies. At the highest level, elimination controls were identified as the most effective intervention. High-risk postures associated with WMSDs—such as forward bending, prolonged sitting, awkward working positions, and manual handling of heavy objects—were substantially reduced through the establishment and enforcement of workplace safety standards. These measures demonstrated a high level of effectiveness, indicating that direct removal of ergonomic hazards plays a critical role in reducing musculoskeletal risk. Substitution controls showed a moderately high effectiveness. The replacement of non-ergonomic seating and equipment with physiologically supportive alternatives, including cushioned seat pads and chairs with appropriate lumbar and arm support, contributed to improved physical comfort and a reduced likelihood of musculoskeletal injury. At the engineering control level, ergonomic workstation redesign based on workers' anthropometric dimensions was implemented. This included the use of ergonomically appropriate tables and chairs, optimization of sewing area layouts to facilitate efficient movement, and the introduction of preventive maintenance schedules to ensure reliable machine performance. These engineering interventions demonstrated a moderate level of effectiveness in reducing unnecessary physical exertion during work activities. Administrative controls were associated with a moderately low level of effectiveness. Interventions included restructuring work schedules to limit continuous sitting to no more than two hours, introducing regular rest breaks tailored to individual physical capacity, implementing targeted stretching exercises for frequently affected muscle groups (e.g., neck, shoulders, back, knees, and feet), and applying the 5S methodology to improve workspace organization. Clear safety protocols were also established to promote safe work practices. Finally, personal protective equipment (PPE) represented the lowest tier of control and demonstrated low effectiveness. PPE was primarily used to reduce localized vibration exposure, particularly to the feet during sewing tasks, and to provide additional ergonomic support. While beneficial as a supplementary measure, PPE alone offered limited protection compared with higher-level control strategies. (Table 6).

Table 6. Hierarchy of Ergonomics controls for WMSDs.

Control	HEC controls for WMSDs	Effectiveness
Elimination	High-risk postures associated with musculoskeletal disorders (MSDs), such as bending, prolonged sitting, awkward positions, and manual handling of heavy objects. The establishment of workplace safety standards helped reduce these risks significantly	high
Substitution	Selecting chairs and equipment that support physiology, such as cushioned seat pads and chair arms that provide lumbar support, decreases the risk of musculoskeletal injury and enhances physical comfort	moderately high
Engineering	Designing the workstations for anthropometric dimensions, incorporating ergonomically appropriate tables and chairs. The spatial layout of sewing areas was optimized for efficiency and ease of movement. Preventive maintenance schedules were also implemented to ensure machinery functioned reliably, thereby reducing unnecessary physical exertion.	moderate
Administrative	Work schedules were reorganized to limit continuous sitting to a maximum of two hours, with regular breaks based on individual	moderately low

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	physical capacity. Targeted stretching routines for commonly affected muscle groups (e.g., neck, shoulders, back, knees, and feet) were incorporated. The 5S methodology was applied to workspace organization, and clear safety protocols were established.	
PPE	PPE was introduced to reduce localized vibration, particularly to the feet, during sewing tasks. Workers were encouraged to wear appropriate gear that supports ergonomic performance and minimizes physical risk.	low

3.6. Integration of Ergonomic Risk Assessment, Workload, and Control Strategies

Figures 2 and 3 jointly illustrate the relationship between ergonomic risk exposure, workload characteristics, and control strategies among informal sewing workers. Figure 2 summarizes the ergonomic risk assessment, showing widespread exposure to prolonged sitting, forward bending, repetitive movements, and awkward postures involving the neck, trunk, and upper limbs, indicating elevated biomechanical risk across routine sewing tasks. Figure 3 links these identified ergonomic hazards with mental workload dimensions, particularly physical and performance demands, and maps them onto the Hierarchy of Ergonomic Controls (HEC) model, demonstrating how higher-order controls address primary ergonomic risks while lower-level controls manage residual exposure. Together, the figures depict a structured progression from ergonomic risk identification to risk management within the study framework. (Figure 2, 3)

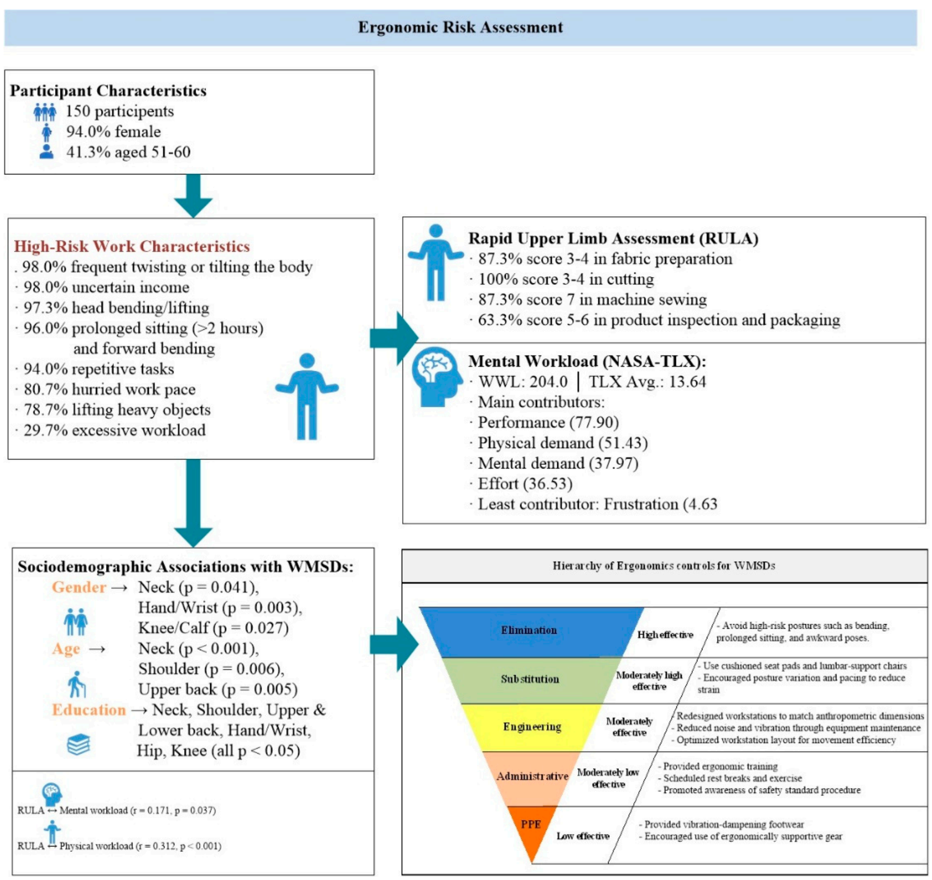

Figure 2. Summaries of Ergonomic risk assessment among Informal Sewing Workers.

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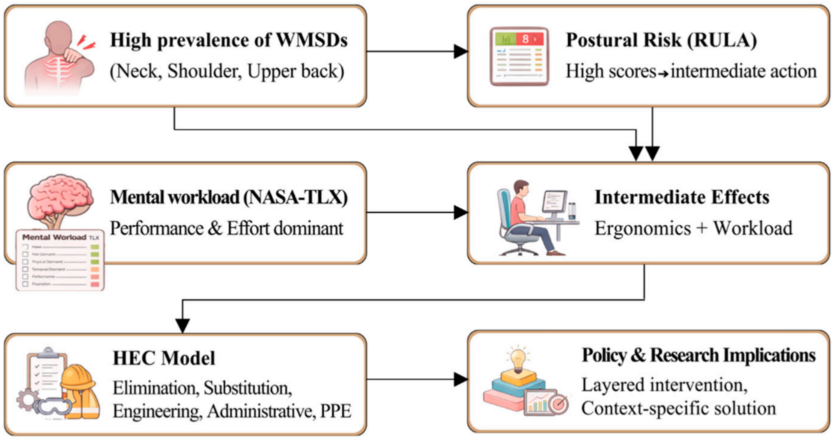

Figure 3. Linking Ergonomic Risks, Workload, and the HEC Model.

4. Discussion

This study provides robust empirical evidence on the interrelated roles of ergonomic risk exposure, mental workload, and work-related musculoskeletal disorders (WMSDs) among informal sewing workers in Thailand. By integrating physical ergonomic assessment (RULA), mental workload evaluation (NASA-TLX), and a prevention framework grounded in the Hierarchy of Ergonomic Controls, the findings extend existing occupational health literature on informal labor settings and offer context-specific intervention pathways.

4.1. Ergonomic Risk Exposure in Informal Sewing Work

The widespread exposure to high-risk postures—prolonged sitting, repetitive movements, forward bending, and awkward trunk and neck positions—observed in this study is consistent with evidence from textile and garment workers across Asia and Africa. Previous studies among sewing machine operators in Nigeria, India, and Indonesia have similarly identified sustained static postures and repetitive upper-limb movements as dominant ergonomic hazards driving musculoskeletal morbidity [5,6,29]. The predominance of female workers further amplifies vulnerability, reflecting gendered labor segmentation within informal economies. Loewenson (2021) and Sverdlik et al. (2024) emphasize that informal female workers often experience compounded risks due to limited bargaining power, absence of labor protections, and economic precarity, which restrict opportunities to modify hazardous work conditions. The near-universal report of income uncertainty in the present study underscores this structural vulnerability and aligns with broader frameworks linking informal employment to occupational health inequities.

4.2. Sociodemographic Inequalities and WMSD Burden

The strong associations between educational attainment and both ergonomic risk exposure and WMSD prevalence observed in this study are particularly noteworthy. Workers with lower than high school education experienced significantly higher exposure to repetitive tasks, awkward postures, and heavy lifting, as well as higher prevalence of WMSDs across multiple anatomical regions. This finding supports earlier research indicating that lower educational levels are associated with reduced ergonomic awareness, limited access to adaptive strategies, and constrained agency to negotiate safer work practices [3,9]. Interestingly, younger workers (< 60 years) reported higher prevalence of spinal WMSDs than older workers. Similar patterns have been reported in studies of agricultural and industrial workers, where younger individuals often sustain higher workloads and longer daily exposure durations, leading to earlier onset of musculoskeletal symptoms [10,29]. This finding challenges assumptions that WMSDs are primarily age-driven and highlights the role of cumulative exposure intensity.

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4.3. Mental Workload as a Contributing Ergonomic Risk

The NASA-TLX findings demonstrate that informal sewing work imposes not only physical strain but also substantial mental workload, particularly in the performance and physical demand dimensions. The high performance workload observed mirrors findings from textile manufacturing and other precision-based occupations, where productivity pressure and quality expectations contribute significantly to perceived workload [12,14]. The significant correlation between physical demand and overall workload reinforces ergonomic models suggesting that physical and cognitive loads interact synergistically rather than independently. Prior studies among nurses, air-traffic trainees, and manufacturing workers have demonstrated that elevated mental workload can exacerbate physical fatigue and increase the risk of musculoskeletal injury [11,13,26]. In the present study, even though mental demand showed a weaker correlation, its statistical significance indicates that sustained attention and precision demands inherent in sewing tasks may contribute to cumulative strain.

4.4. Implications of the Hierarchy of Ergonomic Controls

The graded effectiveness of ergonomic interventions identified in this study strongly aligns with established occupational safety theory. Elimination and substitution controls demonstrated the greatest effectiveness, consistent with prior research emphasizing that upstream hazard control yields more sustainable risk reduction than behavior-dependent measures [16,19]. Engineering controls, including anthropometrically designed workstations, showed moderate effectiveness, echoing findings from workstation redesign studies among sewing operators and apparel workers [8,27,28]. Administrative controls and PPE were least effective, reinforcing evidence that such measures should serve as complementary strategies rather than primary solutions [15,18]. Importantly, in informal work settings where financial and infrastructural constraints limit large-scale engineering interventions, multicomponent and participatory ergonomic programs have shown promise. Quasi-experimental studies demonstrate that combining low-cost engineering modifications with task reorganization and worker education can yield sustained reductions in WMSDs [20].

4.5. Practical and Policy Recommendations

Based on the findings and existing evidence, several targeted recommendations emerge:

1) Prioritize low-cost elimination and substitution strategies, such as redesigning work sequences to reduce prolonged static postures and replacing non-ergonomic seating with lumbar-supportive chairs.
2) Integrate mental workload management into ergonomic interventions by addressing performance pressure, pacing of work, and rest scheduling.
3) Implement community-based ergonomic training, particularly for workers with lower educational attainment, to enhance ergonomic literacy and self-protective behaviors.
4) Strengthen policy recognition of informal workers, aligning with regional occupational safety frameworks in Southeast Asia that increasingly acknowledge informal labor but remain weak in enforcement [17].
5) Adopt participatory ergonomics models, engaging workers, community leaders, and local health authorities to ensure contextual feasibility and sustainability.

4.6. Strengths, Limitations, and Future Research

The integration of validated ergonomic and mental workload tools with a structured prevention framework represents a key strength of this study. However, the cross-sectional design limits causal inference, and the single-province setting may restrict generalizability. Future research should explore longitudinal intervention outcomes, incorporate emerging technologies such as automated

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RULA and machine-learning-based posture assessment [4,23], and examine psychosocial stressors alongside physical and mental workload.

5. Conclusions

In summary, informal sewing workers experience substantial ergonomic and mental workload risks that contribute to a high burden of WMSDs. Addressing these challenges requires prioritizing higher-order ergonomic controls, integrating mental workload considerations, and embedding interventions within community-based and policy-supported frameworks. Such approaches are essential for reducing occupational health inequities among informal workers in low- and middle-income countries.

6. Patents

The authors declare that no patents or patent applications are associated with the findings presented in this manuscript.

Author Contributions: Conceptualization, R.J. and N.T.; methodology, R.J., M.R., and N.T.; software, R.J.; validation, R.J., M.R., R.K., W.J., and W.C.; formal analysis, R.J. and M.R.; investigation, R.J., M.R., and R.K.; resources, N.T. and R.K.; data curation, R.J. and M.R.; writing—original draft preparation, R.J.; writing—review and editing, N.T., M.R., and W.C.; visualization, R.J. and R.K.; supervision, N.T.; project administration, N.T.; funding acquisition, N.T. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of Ubon Ratchathani Rajabhat University (Reference No. HE652033-031/2565).

Informed Consent Statement: Written informed consent was obtained from all participants prior to their enrollment in the study. Before data collection, participants were fully informed about the study objectives, research procedures, types of data to be collected, potential risks and benefits, and their rights as research participants, including the right to decline participation or withdraw from the study at any time without penalty. All participants were assured that their information would be treated confidentially and used exclusively for research purposes, with personal identifiers removed to ensure anonymity. Written consent was obtained to confirm voluntary participation and comprehension of the study conditions, in accordance with ethical standards for research involving human subjects and the approval granted by the Ubon Ratchathani Rajabhat University Ethics Committee (Reference No. HE652033-031/2565). The manuscript does not contain any identifiable personal data; therefore, additional informed consent for publication was not required.

Data Availability Statement: The data supporting the findings of this study are not publicly available due to ethical and privacy restrictions, as they contain information that could compromise the confidentiality of the study participants. Anonymized datasets may be made available from the corresponding author upon reasonable request and subject to approval by the relevant ethics committee.

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Abbreviations

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The following abbreviations are used in this manuscript:

FGD	Focus Group Discussion
HEC	Hierarchy of Ergonomic Controls
MSD	Musculoskeletal Disorder
MSU	Mahasarakham University
NASA-TLX	National Aeronautics and Space Administration Task Load Index
NMQ	Nordic Musculoskeletal Questionnaire
OWAS	Ovako Working Posture Analysis System
PHEP-SEA	Public Health and Environmental Policy in Southeast Asia
PPE	Personal Protective Equipment
REBA	Rapid Entire Body Assessment
RULA	Rapid Upper Limb Assessment
SPSS	Statistical Package for the Social Sciences
UBRU	Ubon Ratchathani Rajabhat University
WMSDs	Work-Related Musculoskeletal Disorders
WWL	Weighted Workload

References

1. Loewenson, R. Rethinking the Paradigm and Practice of Occupational Health in a World Without Decent Work: A Perspective From East and Southern Africa. *NEW SOLUTIONS: A Journal of Environmental and Occupational Health Policy.* **2021,** *31* (2), 107-112. https://journals.sagepub.com/doi/abs/10.1177/10482911211017106.
2. Sverdlik, A.; Kothiwal, K.; Kadungure, A.; Agarwal, S.; Machemedze, R.; Verma, S.; Loewenson, R., Understanding the interplay of occupational, public health, and climate-related risks for informal workers: A new framework with findings from Zimbabwe and India. *Social Science & Medicine.* **2024,** *348*, 116750. https://www.sciencedirect.com/science/article/pii/S0277953624001941.
3. Gangopadhyay, S.; Das, S.; Banerjee, S.; Das, S., Occupational Ergonomics and Industrial Hygiene for Evaluation of Health-Related Hazards in Informal Sectors and SMEs. *Safety and Health at Work.* **2022,** *13*, S19-S20. https://www.sciencedirect.com/science/article/pii/S2093791121008635.
4. Su, J.-M.; Chang, J.-H.; Indrayani, N. L. D.; Wang, C.-J., Machine learning approach to determine the decision rules in ergonomic assessment of working posture in sewing machine operators. *Journal of Safety Research.* **2023,** *87*, 15-26. https://www.sciencedirect.com/science/article/pii/S002243752300110X.
5. Okareh, O. T.; Solomon, O. E.; Olawoyin, R., Prevalence of ergonomic hazards and persistent work-related musculoskeletal pain among textile sewing machine operators. *Safety Science.* **2021,** *136*, 105159. https://www.sciencedirect.com/science/article/pii/S0925753521000023.
6. Kanniappan, V.; Palani, V., Prevalence of musculoskeletal disorders among sewing machine workers in a leather industry. *Journal of Lifestyle Medicine*. **2020**, *10* (2), 121. https://pmc.ncbi.nlm.nih.gov/articles/PMC7502893/.
7. Das, S.; Krishna Moorthy, M.; Shanmugaraja, K., Analysis of musculoskeletal disorder risk in cotton garment industry workers. *Journal of Natural Fibers.* **2023,** *20* (1), 2162182. https://www.tandfonline.com/doi/full/10.1080/15440478.2022.2162182.
8. Tondre, S.; Deshmukh, T., Guidelines to sewing machine workstation design for improving working posture of sewing operator. *International Journal of Industrial Ergonomics*. **2019**, *71*, 37-46. https://www.sciencedirect.com/science/article/pii/S0169814118301835.
9. Hulshof, C. T. J.; Colosio, C.; Daams, J. G.; Ivanov, I. D.; Prakash, K. C.; Kuijer, P. P. F. M.; Leppink, N.; Mandic-Rajcevic, S.; Masci, F.; van der Molen, H. F.; Neupane, S.; Nygård, C.-H.; Oakman, J.; Pega, F.; Proper, K.; Prüss-Üstün, A. M.; Ujita, Y.; Frings-Dresen, M. H. W., WHO/ILO work-related burden of disease and injury: Protocol for systematic reviews of exposure to occupational ergonomic risk factors and of the effect of exposure to occupational ergonomic risk factors on osteoarthritis of hip or knee and selected other musculoskeletal diseases. *Environment International.* **2019,** *125*, 554-566. https://www.sciencedirect.com/science/article/pii/S0160412018313679.

 doi:10.20944/preprints202602.1242.v1

10. Chokprasit, P.; Yimthiang, S.; Veerasakul, S., Predictors of Low Back Pain Risk among Rubber Harvesters. *International Journal of Environmental Research and Public Health*. **2022**, *19* (17), 10492. https://www.mdpi.com/1660-4601/19/17/10492.
11. Pamungkas, R. A.; Ruga, F. B. P.; Kusumapradja, R., Impact of Physical Workload and Mental Workload on Nurse Performance: A Path Analysis. *International Journal of Nursing and Health Services (IJNHS)*. **2022**, *5* (2), 219-225. https://ijnhs.net/index.php/ijnhs/article/view/604.
12. Braarud, P. Ø., An efficient screening technique for acceptable mental workload based on the NASA Task Load Index—development and application to control room validation. *International Journal of Industrial Ergonomics.* **2020,** *76*, 102904. https://www.sciencedirect.com/science/article/pii/S0169814119302847.
13. Dönmez, K.; Demirel, S.; Özdemir, M., Handling the pseudo pilot assignment problem in air traffic control training by using NASA TLX. *Journal of Air Transport Management*. **2020,** *89*, 101934. https://www.sciencedirect.com/science/article/pii/S0969699720305172.
14. Basumerda C, Artsitella CR, Setiawan D. Mental workload analysis of workers in the textile manufacturing company during the Covid-19 pandemic using NASA-TLX. *AIP Conference Proceedings*. **2023** ; *2485*(1):050007. https://pubs.aip.org/aip/acp/article-abstract/2485/1/050007/2905984/Mental-workload-analysis-of-workers-in-the-textile?redirectedFrom=fulltext.
15. Soares, C. O.; Pereira, B. F.; Pereira Gomes, M. V.; Marcondes, L. P.; de Campos Gomes, F.; de Melo-Neto, J. S., Preventive factors against work-related musculoskeletal disorders: narrative review. *Rev Bras Med Trab*. **2019**, *17* (3), 415-430. https://pubmed.ncbi.nlm.nih.gov/32368676/.
16. Lyon, B. K.; Popov, G., Risk treatment strategies: Harmonizing the hierarchy of controls and inherently safer design concepts. *Professional Safety*. **2019**, *64* (05), 34-43. https://onepetro.org/PS/article-abstract/64/05/34/33548/Risk-Treatment-Strategies-Harmonizing-the?redirectedFrom=fulltext.
17. Tang, K. H. D., A comparative overview of the primary Southeast Asian safety and health laws. *International Journal of Workplace Health Management.* **2020,** *13* (6), 601-632. https://www.emerald.com/ijwhm/article-abstract/13/6/601/160479/A-comparative-overview-of-the-primary-Southeast?redirectedFrom=fulltext.
18. Odebiyi DO, Okafor UAC. Musculoskeletal disorders, workplace ergonomics and injury prevention. In: *Ergonomics–New Insights*. Rijeka: IntechOpen; **2023**. https://www.intechopen.com/chapters/84280.
19. Ajslev, J. Z. N.; Møller, J. L.; Andersen, M. F.; Pirzadeh, P.; Lingard, H., The Hierarchy of Controls as an Approach to Visualize the Impact of Occupational Safety and Health Coordination. *International Journal of Environmental Research and Public Health*. **2022**, *19* (5), 2731. https://www.mdpi.com/1660-4601/19/5/2731.
20. Esmaeili, R.; Shakerian, M.; Esmaeili, S. V.; Jalali, M.; Pouya, A. B.; Karimi, A., A multicomponent quasi-experimental ergonomic interventional study: long-term parallel four-groups interventions. *BMC Musculoskeletal Disorders*. **2023**, *24* (1), 107. https://pubmed.ncbi.nlm.nih.gov/36759793/.
21. Yavuz, Ş.; Gür, B.; Çakır, A. D.; Köse, D. A., investigation of the posture positions of the apparel workshop employees with the REBA and RULA method. *Hittite Journal of Science and Engineering*. **2021**, *8* (2), 149-160. https://doaj.org/article/e4897855cda646448f6f33f81beaa9ae.
22. Nugraha, A.; Widajati, N.; Guan, N. Y.; Febriyanto, E. C.; Oktavia, N. D., Risk Analysis of Work Posture and Body Mass Index to Musculoskeletal Disorders among Librarians at Universitas Airlangga. T*he Indonesian Journal of Occupational Safety and Health*. **2024**, *13* (2), 145-155. https://e-journal.unair.ac.id/IJOSH/article/view/52079.
23. Nayak, G. K.; Kim, E., Development of a fully automated RULA assessment system based on computer vision. *International Journal of Industrial Ergonomics*. **2021**, *86*, 103218. https://www.sciencedirect.com/science/article/pii/S0169814121001360.
24. Akyeampong, J.; Udoka, S.; Caruso, G.; Bordegoni, M., Evaluation of hydraulic excavator Human–Machine Interface concepts using NASA TLX. *International Journal of Industrial Ergonomics*. **2014**, *44* (3), 374-382. https://www.sciencedirect.com/science/article/pii/S0169814113001479.
25. Tan, Y. S.; Zalzuli, A. D.; Ang, J.; Ho, H. F.; Tan, C., Understanding the workload of police investigators: a human factors approach. *Journal of police and criminal psychology*. **2022**, *37* (2), 447-456. https://link.springer.com/article/10.1007/s11896-022-09506-w.

doi:10.20944/preprints202602.1242.v1

26. Galy, E.; Paxion, J.; Berthelon, C., Measuring mental workload with the NASA-TLX needs to examine each dimension rather than relying on the global score: an example with driving. *Ergonomics*. **2018**, *61* (4), 517-527. https://pubmed.ncbi.nlm.nih.gov/28817353/.
27. Ahmad, A.; Javed, I.; Abrar, U.; Ahmad, A.; Jaffri, N. R.; Hussain, A., Investigation of ergonomic working conditions of sewing and cutting machine operators of clothing industry. *Industria Textila*. **2021**, *72* (3), 309-314. https://eprints.um.edu.my/28446/.
28. Nagaraj, T. S.; Jeyapaul, R.; Mathiyazhagan, K., Evaluation of ergonomic working conditions among standing sewing machine operators in Sri Lanka. *International Journal of Industrial Ergonomics*. **2019**, *70*, 70-83. https://www.sciencedirect.com/science/article/pii/S0169814118304888.
29. Das, B., Work-related musculoskeletal disorders in agriculture: Ergonomics risk assessment and its prevention among Indian farmers. *Work*. **2023**, *76*, 225-241. https://pubmed.ncbi.nlm.nih.gov/36806533/.
30. Nur, I.; Iskandar, H.; Ade, R., The Measurement of Nurses'mental Workload Using Nasa-Tlx Method (A Case Study). *Malaysian Journal of Public Health Medicine*. **2020**, *20* (Special1), 60-63. https://mjphm.org/index.php/mjphm/article/view/705.