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Ergonomic and Biomechanical Risk Assessment of ICU Nursing Tasks for Engineering-Based Intervention Strategies

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ABSTRACT

Nurses working in Intensive Care Units (ICUs) are highly vulnerable to work-related musculoskeletal disorders (WMSDs) due to physically demanding tasks such as patient handling, prolonged static postures, and repetitive movement. This study aimed to assess ergonomic risk levels and identify predictors of work-related musculoskeletal disorders among 82 ICU nurses using self-administered questionnaires and the Rapid Entire Body Assessment (REBA). The most affected body regions were the lower back (87.0%), neck (85.2%), and upper back (85.2%). Patient-handling tasks, particularly lifting from wheelchairs, were associated with the highest ergonomic risk (REBA score = 11, indicating a very high risk). Nearly half of the participants were classified as medium risk (48.1%), followed by high risk (44.4%) and very high risk (7.4%). Duration of employment, lifting to shoulder height, and high REBA scores (≥8) were significant predictors of total WMSD scores ($p < 0.05$). Demographic factors, including age, BMI, and gender, were not significant ($p > 0.05$). Cumulative ergonomic exposure is the main contributor to WMSDs among ICU nurses rather than personal factors. Therefore, engineering-based interventions, including the use of mechanical assistive devices, height-adjustable beds, and ergonomic training, are recommended to reduce biomechanical load and improve workplace safety.

Keywords: Ergonomic risk assessment; work-related musculoskeletal disorders; rapid entire body assessment; ICU nurses; engineering-based interventions

INTRODUCTION

Musculoskeletal health problems remain a persistent concern in nursing profession particularly in environments characterised by physically demanding clinical duties (Wang et al. 2024). Nursing personnel consistently report musculoskeletal complaints across diverse healthcare systems with symptoms that frequently involve lower back, neck, and shoulders (Jacquier-Bret & Gorce 2025). In intensive care units (ICU), routine clinical activities often require nurses to perform physically strenuous tasks including patient repositioning, awkward postures and prolonged standing (Aleid et al. 2021; Lu et al. 2024). Such task-related physical demands contribute to cumulative biomechanical stress on musculoskeletal system over time (Banks et al. 2024).

Despite growing awareness of work-related musculoskeletal disorders (WMSDs) among nurses, intensive care unit (ICU) environments remain challenging due to the complexity and intensity of care delivery (Detroja et al. 2025). ICU nurses are required to manage critically ill patients who often have limited mobility, necessitating frequent manual handling, patient transfers, bed repositioning, and sustained static or awkward postures during monitoring and procedural tasks (Johnson et al. 2023; Yang et al, 2025). These activities are frequently performed under time pressure and in limited spaces, further increasing physical strain and biomechanical loading on the musculoskeletal system (Adams & Nino 2024; Zhou et al. 2025).

Previous research has shown that sustained exposure to high physical demands in ICU settings is associated with increased ergonomic risk and a greater prevalence of musculoskeletal symptoms, particularly involving the lower back, neck, and upper extremities (Aleid et al. 2021; Cezar-Vaz et al. 2023). Nevertheless, much of the current evidence has predominantly relied on symptom prevalence surveys or self-reported exposure to risk factors, while relatively few studies have undertaken detailed task-based ergonomic and biomechanical assessments capable of quantifying posture-related risk and mechanical loading during specific ICU nursing activities (Lohne et al. 2024; Gao et al. 2025).

From an occupational ergonomics and engineering perspective, systematic assessment tools such as observational ergonomic methods, including the Rapid Entire Body Assessment (REBA), and biomechanical risk models are essential for identifying high-risk tasks and postures that contribute to cumulative musculoskeletal loading (Hignett & McAtamney 2000; Kotadiya et al. 2022; Zare et al. 2014). These assessments provide objective, task-level evidence that can inform the design of targeted intervention strategies, including engineering controls, assistive devices, workspace redesign, and task reconfiguration (Abdul Rahman et al. 2025; Robielos et al. 2019). Lack of detailed task-specific ergonomic evaluation, intervention may be insufficient to address the distinct biomechanical demands encountered in ICU nursing practice. Therefore, comprehensive ergonomic and biomechanical risk assessment of ICU nursing tasks is critical to bridge the gap between epidemiological findings and practical intervention development. By integrating ergonomic assessment with biomechanical considerations, this study aims to support the development of engineering-based intervention strategies that are context-specific, evidence-driven, and capable of reducing musculoskeletal risk while maintaining the quality and efficiency of critical patient care. In the absence of this association, developing practical, evidence-based ergonomic interventions is challenging.

This study aims to evaluate ergonomic and biomechanical risks associated with routine nursing tasks in ICU through task-based assessment. Specifically, the study seeks to identify high-risk postures and activities, quantify levels of ergonomic and biomechanical exposure, and determine tasks that contribute most substantially to cumulative musculoskeletal loading among ICU nurses. By integrating ergonomic risk assessment with biomechanical considerations, this study contributes objective, task-level evidence to support the development of engineering-based intervention strategies, including ergonomic redesign, assistive technologies, and task modification. The findings are expected to inform evidence-driven interventions that enhance occupational safety, reduce musculoskeletal risk, and promote sustainable work practices in high-demand critical care environments.

METHODOLOGY

STUDY DESIGN AND SAMPLING

This cross-sectional study was conducted over a five-month period from March to July 2024. Participants were selected based on the inclusion criteria of having at least one year of working experience in various ICU wards, namely 4T/ Belakang (URK), 6 Utara, 1 Fairuz, 1 Kristal 1 and 2, 1 Mutiara, Surgical ICU (SICU), 2 Delima, Cardiac Rehabilitation Ward (CRW), and Trauma ICU. Nurses who were pregnant during the data collection period, had physical disabilities, or had a history of prior or current musculoskeletal injuries or trauma were excluded from the study. These exclusion criteria were applied to reduce potential confounding factors that could affect the accuracy of the findings. The required sample size was determined using a single-proportion formula.

$$N = (Z_{1-\alpha})^2 \times \frac{P\,(1-p)}{d^2}$$

N = number of samples

$Z_{1-\alpha} = Z_{0.95}$= 1.96 (For Confidence Interval of 95%, Z=1.96; normal distribution table)
P = prevalence from previous study
d = Precision

Hence,

P = 77.2% = 0.772 (Based on the previous study's prevalence by Sun et al. (2023)
d = 0.10

After considering a 20% expected dropout and non-response rate, the final sample size was set at 82 participants. The study used a combination of purposive and simple random sampling methods. Purposive sampling ensured adequate representation across all ICU wards, while simple random sampling within each ward reduced selection bias. The number of participants selected from each ward was calculated using a sampling fraction formula: the overall sample size was divided by the total population, then multiplied by the number of nurses in each ward.

$$\frac{n}{Population\ Size} \times N =$$

Where, n = Total Sample Size (105 respondents)
Population size =The Total Intensive Care nurses is 243
N=Total nurses in each ward

This sampling method ensured that the study included a diverse and representative group of ICU nurses. Ethical approval was obtained from the Human Research Ethics Committee (HREC) of Universiti Sains Malaysia (USM) (JEPeM Code: USM/JEPeM/KK/23121006) on 25 February 2024. A formal request letter was also sent to the respective organisation to obtain permission to conduct the study. One week later, potential participants were informed about the study's objectives, procedures, and their rights, including confidentiality and the right to voluntary participation. All participants were provided with an information sheet and gave written informed consent for participation and publication prior to data collection.

RESEARCH INSTRUMENT

This study employed two primary instruments: a self-administered questionnaire and an ergonomic risk assessment conducted using the Rapid Entire Body Assessment (REBA) method. The questionnaire consisted of three sections to measure the prevalence of WMSD among ICU nurses. Section A comprised demographic information adapted from the *Guidelines on Ergonomic Risk Assessment at the Workplace* (Department of Occupational Safety and Health, 2017). Section B addressed risk factors related to work-related musculoskeletal disorders (WMSDs) adapted from Raithatha and Mishra (2016). Section C utilised the Cornell Musculoskeletal Discomfort Questionnaire (CMDQ) for assessing musculoskeletal discomfort across different body regions (Hedge et al. 1999).

The ergonomic risk assessment was performed using the *REBA Employee Assessment Worksheet*. The REBA assessment has two main components: Part A evaluates the posture of the neck, trunk, and legs. Part B assesses the posture of the upper arm, lower arm, and wrist. Each body segment is scored based on observed posture, with adjustments made in accordance with REBA guidelines. For Part A, the neck, trunk, and legs were observed as nurses performed their regular tasks. Each posture was rated on a 4-point scale based on how far it deviated from a neutral position:

1 point: Neutral or relaxed position
2 points: Slightly flexed, extended, rotated, or bent
3 points: Moderately flexed, extended, rotated, or bent
4 points: Severely flexed, extended, rotated or bent

For Part B, the assessor examined the positions of the wrist, lower arm, and upper arm while nurses performed nursing activities. Each was rated on a 3-point scale:

1 point: Neutral or relaxed position
2 points: Slightly raised or lowered from shoulder level or abducted
3 points: Moderately raised or lowered from shoulder level or abducted

The total REBA score was calculated by combining
the scores from Parts A and B. A higher REBA score indicated a greater ergonomic risk and a higher likelihood of developing WMSDs. The results were used to plan targeted interventions to reduce ergonomic risk among ICU nurses.

The REBA risk levels were categorised as follows:

1 = Negligible risk
2–3 = Low risk
4–7 = Medium risk
8–10 = High risk
≥11 = Very high risk

DATA COLLECTION AND PROCEDURES

The data collection process was conducted in two stages. In the first stage, participants completed a 30-minute face-to-face interview using a self-administered questionnaire. This approach enabled the researcher to clarify any unclear questions, reduce the likelihood of misunderstanding, and enhance the accuracy and reliability of the responses.

In the second stage, an ergonomic risk assessment (ERA) was carried out using the Rapid Entire Body Assessment (REBA) method. Trained assessors observed

participants performing routine nursing tasks and recorded their postures using photographs and video, in accordance with standard assessment procedures. This observational method provided a detailed and objective analysis of body postures, which was then used to determine ergonomic risk levels. The REBA scores were classified into established risk categories to provide a comprehensive evaluation of the physical strain ICU nurses experience during their work.

DATA ANALYSIS

All data were analysed using IBM SPSS Statistics version 27. Descriptive statistics were used to summarise ergonomic risk levels, WMSD symptom scores, and work characteristics among ICU nurses. Binary logistic regression was used to examine the association between WMSD symptoms and REBA level. Subsequently, a multiple linear regression (MLR) analysis was performed to examine the relationship between total WMSD symptom scores and the identified risk factors. This regression model identified significant predictors of WMSD symptoms, including relevant demographic and occupational variables.

RESULTS AND DISCUSSION

SOCIODEMOGRAPHIC OF THE RESPONDENTS

A total of 82 ICU nurses participated in this study, of whom 85.4% ($n = 70$) were female and 14.6% ($n = 12$) were male (Table 1). The majority (72.7%, n=72) were married. The mean age was 34.7 years, and the average employment duration was 11.4 years. The mean body mass index (BMI) was 26.2 kg/m². Based on BMI classification, 7.3% (n=6) were underweight, 59.8% (n=49) had normal weight, 25.6% (n=21) were overweight, and 7.3% (n=6) were obese. More than half (54.9%, n=45) of the nurses worked in wards with fewer than five staff members, while 45.1% (n=37) worked with more than 5. None of the participants were current smokers. Additionally, 17.1% (n=14) reported having a medically diagnosed illness that required ongoing medication.

TABLE 1. Sociodemographic Characteristics of Respondents

Variables	Category	Frequency (n)	Percentage (%)	Mean ±SD)
Gender	Female	70	85.4	-
	Male	12	14.6	-
Age (years)	≤ 25	10	12.2	34.7 ±7.8
	26-35	34	41.5	
	36-45	27	32.9	
	≥ 46	11	13.4	
Marital status	Single	22	26.8	-
	Married	60	73.2	
Year of employment	< 10	51	62.2	11.40 ± 6.46
	≥ 10	31	37.8	
Body Mass Index (BMI) (kg/m^2)	Underweight (< 18.5)	6	7.3	26.20 ± 5.06
	Normal (18.5 – 24.9)	49	59.8	
	Overweight (25 – 29.9)	21	25.6	
	Obese (≥ 30)	6	7.3	
Number of people with	< 5 persons	45	54.9	
	≥ 5 people	37	45.1	
Work unit/shift	Day shift	47	57.3	-
	Rotating/Shiftwork	35	42.7	
Disease diagnosed	Yes	14	17.1	-
	No	68	82.9	

WORK CHARACTERISTICS OF NURSES IN INTENSIVE CARE UNITS

Table 2 presents the main ergonomic risk factors identified for ICU nurses, ranked by frequency. The most frequently reported physical stressor was "pushing or pulling heavy objects or people" (24.1%, n=20), indicating that ICU nurses are often exposed to biomechanical strain during routine work. The least reported risk factors were "working for long periods with the head or arms in awkward positions" and "working for long periods with the body in awkward positions," at 6.1 % (n=5) respectively.

These findings align with those of Lin et al. (2020) and Nemera et al. (2024), who found that manual handling tasks, particularly pushing, pulling, and lifting heavy loads, were major contributors to work-related musculoskeletal disorders (WMSDs) among hospital staff. Such activities demand high physical effort, increasing spinal load and muscle strain. In this study, the lower back and shoulders were the most affected body regions. Similarly, Johnson et al. (2023) reported that frequent lifting and patient handling without assistive devices were key ergonomic stressors for nurses. These similarities across studies indicate that physical demands are a common problem in healthcare and highlight the urgent need for ergonomic control measures.

TABLE 2. Work Characteristics of Nurses

Work Characteristics	N (%)			
	Never	Sometimes	Often	Always
Rapid and continuous physical activity	3 (3.7)	42 (51.2)	26 (31.7)	11 (13.4)
Moving or lifting weighty loads	2 (2.4)	36 (43.9)	29 (35.4)	15 (18.3)
Working for long periods with the head or arms in an awkward position	27 (32.9)	38 (46.3)	12(14.6)	5 (6.1)
Working for long periods with the body in an awkward position	26 (31.5)	41 (50.0)	11 (13.0)	5 (5.6)
Lift or lower patients or objects to or from the floor	14 (17.0)	32 (39.0)	27 (32.9)	9 (11.0)
Lift or lower objects to or from shoulder height	6 (7.3)	38 (46.4)	27 (32.9)	11 (13.4)
Work while bent or twisted at the waist	9 (11.0)	26 (31.7)	33 (40.2)	14 (17.1)
Push or pull heavy objects or people	3 (3.7)	10 (12.2)	49 (59.8)	20 (24.3)
Stand in one place or static position (>30 minutes)	5 (6.1)	44 (53.7)	27 (32.9)	6 (7.3)
Perform repetitive motions with hands or wrists	3 (3.7)	38 (46.3)	32 (39.0)	9 (11.0)
Apply pressure with hands or fingers (e.g., to prevent bleeding)	8 (9.8)	27 (32.9)	39 (47.5)	8 (9.8)

PREVALENCE AND DISTRIBUTION OF WMSD SYMPTOMS

Figure 1 shows the prevalence of WMSDs by body region. Musculoskeletal symptoms were common among ICU nurses with 96.3 % (n=79) reporting at least one affected area. The most frequently affected regions were the lower back.

These results are like those of previous studies in critical care settings, which also found the spine and shoulder areas to be most vulnerable to physical strain (Lin et al. 2020; Aleid et al. 2021). Slight differences in reported prevalence between studies may be due to variations in work environment, job design, or staffing patterns. The consistently high rates across several body parts indicate that WMSDs among ICU nurses are widespread and represent a serious occupational issue that needs immediate attention.

Musculoskeletal symptoms in specific anatomical regions can be attributed to the biomechanical demands of nursing work, such as lifting or repositioning patients, standing for extended periods, and working in awkward postures. The findings of this study differ slightly from Nurfadzlina (2016), who found the neck to be the most affected area. In contrast, this study identified a higher prevalence in the lower bac. These differences may be due to workplace conditions, task types, or participant characteristics. Similarly, Aleid et al. (2021) reported a high prevalence of musculoskeletal problems in the lower back and neck. Both studies highlight that lower back and shoulder problems are commonly observed among ICU nurses because of the repetitive and physically demanding nature of their work.

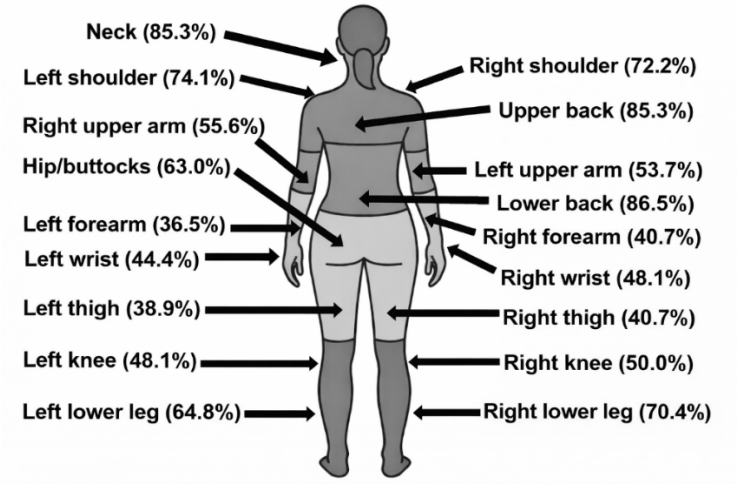

FIGURE 1. Prevalence of WMSDs based on body regions

ERGONOMIC RISKS ASSESSMENT USING REBA

Table 3 presents the ergonomic risk levels associated with common nursing tasks in the ICU, as measured using the Rapid Entire Body Assessment (REBA). The results show that lifting a patient from a wheelchair to a standing position had the highest REBA score (11), indicating a very high ergonomic risk. This task requires considerable force and awkward postures, which increase spinal loading and muscle strain. Tasks such as lifting a patient from a sitting to a standing position and repositioning a patient in bed both recorded high-risk levels (REBA = 8), while lifting a patient from the bed to a sitting position showed a medium risk (REBA = 6). These findings demonstrate that most patient-handling activities in ICU settings expose nurses to biomechanical stress and physical fatigue.

TABLE 3. Levels of ergonomic risk for nursing tasks in the ICU

Nursing task	REBA score	Risk level
Lifting the patient from the wheelchair to stand	11	Very High Risk
Lifting the patient from sitting to standing	8	High Risk
Positioning the patient in bed	8	High Risk
Lifting the patient from the bed to sit	6	Medium Risk

Manual patient-handling tasks are the main contributors to ergonomic risk and musculoskeletal disorders among healthcare workers. For instance, Clari et al. (2021) and Ayyaz et al. (2023) reported that lifting and repositioning patients were the most hazardous activities, particularly when assistive devices were not used. Similarly, Nemera et al. (2024) highlighted that the combination of an awkward posture and a heavy load during patient transfer significantly increases the risk of lower back and shoulder injuries. In another study, Detroja et al. (2025) found that ICU nurses often scored high on the REBA due to repetitive bending and trunk twisting while caring for immobile patients.

From a theoretical perspective, these results align with biomechanical load theory, which explains that repetitive physical loading, especially on the spine and upper limbs, increases the risk of tissue damage and musculoskeletal disorders (National Research Council US & Institute of Medicine, 2021). They also support the cumulative trauma disorder model, which suggests that prolonged exposure to repetitive and forceful movements leads to the gradual deterioration of musculoskeletal health (Davis & Kotowski, 2021). Minor differences between this study and previous findings may be due to variations in workplace design, availability of assistive equipment, and task allocation systems across hospitals. Nevertheless, consistent evidence across multiple studies emphasises that ICU nursing inherently involves high biomechanical demands, which require urgent ergonomic interventions.

ASSOCIATION BETWEEN ERGONOMIC EXPOSURE AND WMSD SYMPTOMS

Nurses with high ergonomic risk exposure (REBA score ≥ 8) were significantly more likely to experience musculoskeletal symptoms in several body regions. (Table 4). After adjustment for age, sex, years of service, and ward staffing ratio, significant associations were observed for the neck (AOR = 2.49, 95%CI=1.09 – 5.68), shoulder (AOR = 2.86, 95%CI=1.26 – 6.48), upper back (AOR = 2.42, 95%CI = 1.07 – 5.48), lower back (AOR = 3.77, 95%CI =1.54 – 9.25), and wrist/hand (AOR = 3.00, 95%CI = 1.28 – 7.04)) regions. Further analyses showed that high ergonomic risk also increased the likelihood of spinal symptoms (AOR = 4.06, 95%CI = 1.62 – 10.18) and upper-limb symptoms (AOR = 3.35, 95%CI = 1.41 – 7.99). These results support a strong relationship between awkward postures, repetitive tasks, and the development of work-related musculoskeletal disorders (WMSDs).

These findings are consistent with prior research showing that the ICU environment is high-risk for musculoskeletal injuries due to frequent patient handling, static postures, and heavy lifting. Sun et al. (2023) reported a WMSD prevalence of 77.2% among nurses, with the lower back, neck, and shoulders being the most affected. Similarly, Detroja et al. (2025) found high rates of musculoskeletal disorders among ICU nurses, attributing them to ergonomic stressors in patient care. In another hospital-based study, ICU nurses reported a prevalence of 92.7% for musculoskeletal complaints, particularly in the lower back and neck. Moreover, Kim et al. (2024) observed that repetitive upper-limb movements and awkward posture were associated with increased wrist and hand pain among nurses with longer employment durations.

No significant association was found for the knee or leg region ($p > 0.05$), suggesting that ergonomic strain is more pronounced in the upper body compared to the lower limbs. This trend aligns with findings by Kim & Jeong (2024), who reported that knee complaints were less frequent among ICU nurses due to limited squatting activities. The overall findings indicate that high ergonomic risk does not affect isolated anatomical regions but instead exerts a synergistic impact on both the spinal and upper-limb systems, thereby supporting multifactorial ergonomic theories (Liu et al. 2025).

TABLE 4. Binary Logistic Regression Analysis of High-Risk Ergonomic Exposure (REBA ³8) and WMSD Symptoms among ICU Nurses

Body Region	β	SE	Wald χ2	Adjusted OR (95%CI)	p-value
Neck	0.91	0.43	4.49	2.49 (1.09 – 5.68)	0.034*
Shoulder	1.05	0.42	6.25	2.86 (1.26 – 6.48)	0.018*
Upper Back	0.88	0.41	4.61	2.42 (1.07 – 5.48)	0.032*
Lower Back	1.33	0.46	8.32	3.77 (1.54 – 9.25)	0.004*
Wrist/Hand	1.10	0.44	6.26	3.00 (1.28 – 7.04)	0.015*
Knee/Leg	0.48	0.49	0.96	1.62 (0.62 – 4.19)	0.329
Composite (Spinal Symptoms)	1.40	0.47	0.86	4.06 (1.62 – 10.18)	0.003*
Composite (Upper-Limb Symptoms)	1.21	0.44	7.4	3.35 (1.41 – 7.99)	0.006*

*Adjusted for sex, age, years of service, and ward staffing ratio.
* significance at $\alpha = 0.05$.
b = logistic regression coefficient; SE = standard error; Wald χ^2 = Wald test statistic.

PREDICTORS OF TOTAL WORK-RELATED MUSCULOSKELETAL DISORDER (WMSD) SCORE

The multivariate regression analysis identified three significant predictors of the total WMSD score among ICU nurses: duration of employment (Adj B = 2.98, 95% CI: 0.91- 5.05), lifting or lowering objects to or from shoulder height (Adj B = 3.62, 95% CI: 0.78 - 6.46)), and a high REBA score (≥ 8) (Adj B = 0.74, 95% CI: 0.23 -1.25) (Table 5). The model explained 28% of the variation in total WMSD scores, indicating moderate predictive strength. Other demographic factors, such as age, gender, marital status, and BMI, were not significantly associated with WMSD scores ($p>0.05$).

These results show that ergonomic exposure and years of employment are major contributors to musculoskeletal discomfort among ICU nurses. The positive regression coefficients for employment duration and REBA scores indicate that prolonged exposure to awkward postures, heavy lifting, and static work positions increases strain, especially in the spine and upper limbs. This supports the concept of cumulative ergonomic load, where repeated physical stress over time leads to chronic musculoskeletal problems. These findings are consistent with previous research linking ergonomic risk exposure to the prevalence of WMSD among nurses. Detroja et al. (2025) reported

that longer service years and frequent manual patient transfers were strongly predictive of lower back and shoulder pain. Similarly, Khotari et al. (2022) found that high REBA scores (≥8) were significantly associated with more severe WMSD symptoms, particularly among nurses performing frequent patient repositioning tasks.

The impact of lifting objects to or from shoulder height is consistent with previous ergonomic studies, which show that working with arms elevated above 60° increases shoulder and upper-limb strain. Similar biomechanical findings were discussed by Gorce and Jacquier-Bret (2025), who reported that upper-limb disorders are strongly influenced by repetitive reaching and sustained elevation during nursing activities. Li et al. (2023) further demonstrated that repetitive reaching and arm elevation, combined with static trunk postures, significantly increase the risk of upper-limb disorders in healthcare settings.

The association between longer work duration and higher WMSD scores aligns with Punnett and Wegman (2004), who highlighted that long-term exposure to awkward postures and physical load leads to microtrauma and chronic musculoskeletal pain. Comparable patterns were also observed in more recent studies among nurses in Ethiopia (Nemera et al. 2024) and Asia (Sun et al. 2023), which found that cumulative ergonomic stress and extended employment duration were strong predictors of musculoskeletal discomfort, particularly in the lower back and upper limbs.

In contrast, age, BMI, and gender were not significant predictors of musculoskeletal symptoms among ICU nurses. This result is consistent with recent studies show that ergonomic factors are stronger determinants of WMSDs than personal characteristics (Detroja et al. 2025; Kim & Jeong, 2024; Popova et al. 2025). Punnett and Wegman (2004) highlighted that physical stressors such as awkward postures, repetitive tasks, and prolonged static positions are key contributors to musculoskeletal strain. According to the Biomechanical Loading Theory, repeated and sustained awkward postures cause micro-injury to tissues and cumulative damage over time (Marras & Karwowski, 2006; Marras, 2006).

Similarly, the Cumulative Fatigue Model suggests that continuous exposure without sufficient recovery weakens muscles and joints, increasing the risk of chronic discomfort (Punnett & Wegman, 2004). Recent findings among ICU nurses by Detroja et al. (2025) and Kim and Jeong (2024) also demonstrated that prolonged work exposure and high REBA scores are significant predictors of WMSDs, while demographic factors remain non-significant. Likewise, Popova et al. (2025) reported that occupational load and posture exert more potent effects on WMSD risk than age or BMI.

These results align with multifactorial ergonomic frameworks, which emphasise that task design, physical load, and exposure duration collectively influence musculoskeletal outcomes (Ferguson et al. 2011). Overall, this study reinforces that cumulative ergonomic stress, rather than personal traits, is the leading cause of WMSDs among ICU nurses, emphasising the importance of preventive ergonomic interventions.

TABLE 5. Associated risk factors to Total of Work-related Musculoskeletal Disorders (WMSDs) Score

Risk Factor	SLR[a]		MLR[b]		
	β (95% CI)	p-value	Adjusted B (95%CI)	t-statistics	p-value
Constant	11.27 (–1.18, 23.72)	0.075	9.86 (–1.97, 21.69)	1.69	0.097
Age (years)	–0.02 (–0.23, 0.18)	0.833	–0.08 (–0.39, 0.23)	-0.51	0.612
Gender					
Female	–0.16 (–3.16, 2.84)	0.914	–0.41 (–3.92, 3.09)	-0.23	0.823
Male (ref)					
Marital Status					
Married	–2.08 (–5.42, 1.26)	0.216	–1.89 (–5.07, 1.28)	-1.18	0.242
Single (ref)					
Body Mass Index (BMI)	0.15 (–0.14, 0.43)	0.304	0.11 (–0.17, 0.40)	0.79	0.432
Employment (years)	1.36 (–1.53, 4.24)	0.349	2.98 (0.91, 5.05)	2.96	0.004*

continue...

...cont.

Diagnosed Disease					
Yes	–0.06 (–3.23, 3.12)	0.972	0.24 (–3.07, 3.55)	0.14	0.888
No (ref)					
Lift or Lower Objects to/ from Shoulder Height (Yes)	–3.40 (–8.85, 2.05)	0.216	3.62 (0.78, 6.46)	2.54	0.013*
REBA Score (≥ 8)	–0.20 (–0.93, 0.54)	0.595	0.74 (0.23, 1.25)	2.90	0.005*

[a] Simple Linear Regression, [b] Multiple Linear Regression
Model Summary: F (8, 90) = 5.12, p < 0.001; Adjusted R^2 = 0.28.
***** significance at p< 0.05. (ref) = Reference category.

PRACTICAL AND ENGINEERING IMPLICATIONS OF THE FINDING

The present findings have significant implications for occupational ergonomics and hospital management. ICU nurses are frequently exposed to high ergonomic risks, particularly from repetitive tasks such as lifting, pushing, and pulling, which contribute to musculoskeletal strain. Implementing targeted engineering and administrative interventions is therefore essential to reduce these risks and enhance workforce safety.

Hospitals should prioritise ergonomic improvements such as mechanical lifting devices, height-adjustable beds, and patient transfer aids to minimise shoulder and spinal loading during patient handling. Administrative controls, including job rotation, sufficient rest intervals, and balanced staffing ratios, can further mitigate cumulative biomechanical stress. Regular ergonomic training and education on safe body mechanics should be incorporated into nursing curricula and continuous professional development programmes to promote posture awareness and early symptom management.

Institutional commitment is vital to sustain these efforts. Routine ergonomic assessments using validated tools such as REBA or RULA should be integrated into hospital occupational health surveillance systems to identify high-risk tasks and support evidence-based policy decisions. Embedding ergonomic design principles into ICU workflows can enhance workflow efficiency, reduce injury rates, and contribute to safer, more sustainable healthcare delivery.

CONCLUSION

This study found a high prevalence of work-related musculoskeletal disorders among ICU nurses, predominantly affecting the lower back, neck, and upper back. Patient-handling activities, especially lifting, pushing, and pulling were identified as major ergonomic risks, with REBA scores indicating moderate to very high risk. Longer employment duration, frequent lifting to shoulder height, and elevated REBA scores were significant predictors of musculoskeletal symptoms. Overall, the findings indicate that cumulative ergonomic exposure, rather than demographic characteristics, is the primary contributor to discomfort. Engineering controls, supported by appropriate administrative measures and integrated ergonomic assessment and training, are essential to reduce risk, enhance nurse safety, and support sustainable, high-quality patient care.

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DECLARATION OF COMPETING INTEREST

None.

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