EMPIRICAL RESEARCH QUALITATIVE   `OPEN ACCESS`

Factors Contributing to Muscle Fatigue of Low Back Region in ICU Nurses: A Qualitative Study

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ABSTRACT

Aims: To explore ICU nurses' experiences of back and waist fatigue and establish a basis for developing effective intervention strategies to reduce low back muscle fatigue in the future.

Design: Qualitative study using focus group.

Methods: Eighteen ICU nurses participated in focus group interviews. Data were analysed using Nvivo11.0 software with content analysis.

Results: ICU nurses frequently suffer from lower back pain due to the severity of patient conditions and the use of numerous tubes and catheters, which often lead tounsafe postures. The absence of proper lifting systems exacerbates high-risk postures, contributing to acute lower back muscle injuries. Additionally, inadequate promotion of correct posture and prevention strategies, along with insufficient training on occupational hazards, futher exacerbates the issue.

Conclusions: Human fator, machinery, environments, as well as their interactions significantly affect ICU nurses' experience of low back and waist muscle fatigue.

Reporting Method: Reported according to the SRQR (Standards for Reporting Qualitative Research) guideline.

Impact: Offersnew insights into applying the human-machine-environment theory toto clinical nursing practice research. Highlightsthat the unconscious or passive adoption of poor postures by ICU nurses as a major factor contributing to muscles fatigue. Emphasizes the need for comprehensive intervention programsto prevent work-related low back muscle fatigue among ICU nurses.

Patient or Public Contribution: Based on our findings, we have discussed the result with hospital management highlighting the urgent need for mesures to protect ICU nurses back and waist muscles. We believe this proactive approach is essentialfor ensuring the long-term well-being of healthcare professionals and maintaining the high standards of patient care.

1 | Introduction

The fatigue of the muscles in the lower back and waist can impact the stability of the spinal system, including both the neural control subsystem and the passive subsystem. This may lead to reduced sensitivity of the proprioceptive system, resulting in decreased spinal stability and load-bearing capacity. Extended and repetitive exposure to such conditions may contribute to

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the development of lower back disorders, such as lumbar pain (Buchbinder et al. 2018; Rose et al. 2014). With the rapid development of critical care medicine and the growing demand for health care among the general public, the workload of nurses in intensive care units (ICUs) has significantly risen, leading to accumulated muscle fatigue in the waist and back due to work-related factors, as well as a serious problem of occupational low back pain (OLBP) (Hartvigsen et al. 2018).

2 | Background

Nurse's lower back muscle fatigue is attributed to various factors, with poor posture during work being a significant contributing factor (Maher et al. 2017; Cè et al. 2020). Research shows that when the human body is in a supine position, the load on the lumbar spine is minimal. However, trunk flexion results in an increase compressive and tensile stresses. Rotational movements place additional torsional loads on the spine, further intensifying the stress on the intervertebral discs (Wong et al. 2022; Jain et al. 2020). In the clinical diagnosis and treatment guidelines for non-specific low back pain issued in China in 2022, occupational movements such as frequent bending, twisting, and frequent lifting of heavy objects has been classifed as a yellow warning item among the relevant factors affecting the progression of non-specific low back pain (chronicity, recurrence, exacerbation) (Maher et al. 2017).

However, the protection of the muscles and skeletal system of the operators is overlooked in the nursing operations, with improper working postures and manual lifting frequently occuring in critical care nursing practice (Epstein et al. 2018; Engst et al. 2005). The survey shows that nurses spend 25% of their working time in positions that involve bending or other constraints on the waist (Brusini 2021). A previous investigation of Soylar and Ozer (2018) have demonstrated that there are common adverse working postures in clinical settings, such as manually lifting patients, frequently bending over, and twisting to reach objects. On average, nurses assist patients in turning over 6.9 times per shift, with 27.5% of nurses needing to assist with more than 11 turns per shift. Additionally, 40% of clinical nurses manually move patients more than five times per shift. Over 60% of nurses reported frequently bending over and twisting to pick up objects while on duty. These dynamic or static poor postures increase spinal pressure and cause uneven force distribution on the spine. Such postures often persist, leading to cumulative damage from static load, which can triggers Office Low Back Pain (OLBP). Unfortunately, there are currently few studies that explore the potential changes in these poor work postures during the process of ensuring patient safety. Whether these changes could be beneficial in preventing muscle fatigue related to nurses' back and waist remains unknown (Muscle fatigue related to Nursing Operating, MFrNO) (Oliveira et al. 2018).

The theory of Human-Computer-Environment (HCE) focuses on analysing the three elements of human, computer, and environment (Chauhan and Sondhi 2020). Since its proposal, it has been widely applied in industries such as aviation, manufacturing, nuclear power, and military to improve systems and services (Wang et al. 2021). The National Academy of Medicine in the United States reconginzes the human-machine-environment (HME) system as a crucial set of guiding theories and practical tools for designing medical systems. This framework can provide guidance for the design and implementation of medical systems, such as emhancing team collaboration, optimising systems and processes, and improving human-machine interfaces (Li et al. 2018).

Therefore, this study aims to adopt a qualitative research approach to understand the experience of back and waist fatigue during different nursing operations in the ICUs from the perspectives of ICU nursing managers and ICU nurses. Additionally, it seeks to explore the issue of Muscle Fatigue Related to Nursing Operations (MFrNO) among ICU nurses from the three dimensions of human-machine-environment. This research will provide a scientific basis for developing a future intervention plan to prevent ICU nurses' work-related back and waist muscle fatigue.

3 | Method

3.1 | Study Design

A qualitative descriptive design was used to obtain the experience of ICU nurses' waist and back fatigue during nursing tasks, as well as the occurrence of improper working postures and related influencing factors. Two focuse group interviews were applied in this study.

3.2 | Participants

The research objects in this stage include two categories. The first category consist of ICU nursing managers, with the following inclusion criteria: ICU nursing supervisor/deputy supervisor; voluntarily participation in this research; exclusion criteria is having served as an ICU nursing supervisor/deputy supervisor for less than 1 year. The second category includes ICU charge nurses, with the inclusion criteria being: ICU registered nurses; voluntarily participation in this research. The exclusion criteria are having less than 1 year of ICU work experience and never having served as a charge nurse. Eight nursing supervisors/ deputy supervisors from the central ICU, neurosurgical ICU, neurological ICU, respiratory ICU, and emergency ICU of a comprehensive hospital were recruited for interviews based on convenience sampling. Besides, a total of 10 charge nurses from different ICUs were selected as interviewees.

3.3 | Data Collection

In October 2021, data for this stage were collected through focus group interviews conducted in two separate rounds, both led by the primary researcher. The initial round included eight nursing managers, while the second round encompassed 10 ICU nurses. Before starting the interviews, the researcher provided an overview of the research objectives. Each of the 18 participants introduced themsevles, sharing their names, nicknames, areas of research focus, and personal interests.

TABLE 1 | Interview outline.

BOX pre-encoded open-ended question
1. How are the nursing positions in your ward arranged, and what are the responsibilities and accountability of each position?
2. Do the nurses in your ward ever complain of back and waist pain? What measures have they taken to cope with the pain?
3. What operations can cause back and waist muscle fatigue for nurses in your ward? What preventive measures have you taken?
4. What techniques do you ever adopt to reduce the occurrence of improper work postures?
5. With regard to high-risk procedures or management practices that may result in occupational muscle fatigue among nurses, what potential areas for optimization do you think exist?
6. Do you have any suggestions on enhancing the awareness of ICU nurses regarding the prevention of work-related fatigue in their back and waist muscles?

Throughout the interviews, the researcher posed open-ended questions related to various topics, including the following aspects: the division of labor and duties of nursing positions in the ward; the current prevalence of low back pain among ICU nurses; the factors contributing to low back pain; the impact of low back pain on their work and daily life; and the techniques and strategies for preventing issues that lead to muscle fatigue in the lower back, explored from the perspectives of both managers and nurses. The questions addressed in the interviews are detailed in Table 1.

The primary focus of the research team during the interview is attentive listening. The research team members promptly use their own language to interpret and summarise their understanding of the interviewee's responses. Additionally, they actively reassessed the interviewee's feedback to ensure a precise understanding. To prevent any possible omissions or recording errors during the interview process, a dedicated team member took on-site notes, which were supplemented with audio recordings. With the consent of the interviewees, the research team recorded the entire interview and transcribed the key parts, with one person transcribing and another verifying the content.

3.4 | Data Analysis

NVivo11.0 software was used to conduct specific data analysis through content analysis method (Järvinen and Mik-Meyer 2020; Smith et al. 2009). To ensure a rigorous and comprehensive analysis, the following steps were taken: (1) Carefully listen to the recordings, read through the interview transcripts and memos, and gradually identify key concepts and themes. This process aims to establish a preliminary thematic framework. (2) Systematically search for, extract, and code expressions related to the research within each sentence. This involves constant comparison and analysis with the existing thematic framework. Classify these expressions and revise the framework based on the actual data patterns observed. (3) Deliver the final analysis results to the research subject for verification of content authenticity, ensuring that the findings are reliable and accurate. (4) Extract themes specifically related to ICU nurses' back and waist MFrNO. This step involves a meticulous review of the data to identify patterns and trends. In case of any inconsistencies or disputes, I collaborate with another

master's student on the research team during the data encoding process, discussing and resolving issues in our team meetings. Adhering to the principles of hermeneutic phenomenological analysis, we selected at least three participants' quotations to support each proposed theme (Smith 2011). Table 2 shows an example of theme identification.

3.5 | Rigour

3.5.1 | Group Focused Interview Phase

To ensure a stress-free interview experience and foster a relaxed communication environment, the interview location was deliberately chosen to be the training room with which the interviewees were familiar. Before beginning the interview, the group engaged in casual discussions regarding a current clinical hot topic—epidemic prevention and control—as well as their personal hobbies. To promote open and natural discussions, interrogative questions were avoided, and dialogue was encouraged.

3.5.2 | Data Collection and Analysis Phase

To ensure accurate transcription of interview information, notes and recordings were collated and double-checked by two researchers. The data analysts had solid theoretical and practical backgrounds in phenomenological research. Additionally, the mentor and research group members engaged in multiple group discussions throughout the data analysis process to guarantee the accuracy of the fingdings.

3.6 | Ethical Considerations

The study adhered to the ethical standards stated in the Declaration of Helsinki and its subsequent amendments (The World Medical Association 2013). Before commencing the research, approval was obtained from the Ethics Review Committee of Xiangya Nursing School of Central South University (no. 202109003). Prior to the interviews, the researcher provided participants with information about the study's purpose, significance, on-site observation methods, as well as the rights and obligations of the participants.

TABLE 2 | An example of data analysis.

Meaning units	Primary codes	Sub-theme	Theme
"When I was young, I really didn't know that I needed to reduce the deviation of the body's gravity line when operating, so I often used a single leg to support my body to get things from the head or foot of the bed, completely forgetting that I needed to move one step forward to the left or right" (H 04) "I see that the young nurses on our ward really don't know how to save their strength, or maybe they think they are healthy so they don't think about saving their strength to protect their backs? I don't get it." (N 06)	Some young nurses don't know some basic principles of ergonomics or are not sufficiently aware of applying the principles of ergonomics	The principles of human mechanics were not well applied in practice, especially for young nurses	"Human" factor
"If only there was lifting equipment installed attaching to the ceiling, it would be extremely beneficial" (N 5). "Initially, patients were transported for examinations using a bed, but this frequently caused collisions and wear and tear on the bed, leading to frequent repairs and high maintenance costs. Our beds cost over 1 million yuan each, and there are various attachments, bedside tables, and other expensive items, so to prevent damage to these items, we chose to manually carry the patients to a stretcher instead" (H 04)	Most department lacked a patient transfer system, resulting in all patient lifting and moving being done manually	Lack of patient lifting system equipped	"Machine" factor
"During our new employee orientation, the hospital only provided a one-hour occupational safety training course, which mainly covers the importance of preventing needlestick injuries and the handling procedures in case of needlestick injuries" (H 03) "I think that the hospital occupational safety training is organised only 2 times a year is somewhat less, each time to analyse the case of occupational exposure to blood-borne pathogens, there are experts repeatedly emphasise the standard prevention, post-exposure treatment, the recognition of work-related injuries, etc., a lot of content, but about occupational low back pain is only a little bit of explanation, did not make it clear, and we still do not understand" (tilted head, spreading out her hands) (H 05)	Hospital occupational safety training is almost exclusively about prevention and control related to infectious diseases	Hospitals' healthy workplace culture is flawed	"environment" factor

Subsequently, written informed consent forms were signed by the participants. The names were anonymized with codes in the interview records and data analysis, ensuring the protection of participants' personal privacy.

4 | Findings

All 18 ICU nursing staff are female, aged between 29 and 49, with ICU nursing experience ranging from 2 to 30 years (Table 3). The duration of the interviews for the two groups were 90 and 105 min, respectively. The five categories derived from the data provide a detailed description of the ICU nurses experience with muscle fatigue related to their waists and backs. The categories and subcategories are displayed in Table 4.

4.1 | Muscle Fatigue and Pain in the Lower Back and Waist Among ICU Nurses

4.1.1 | The Issue of Muscle Fatigue and Pain in the Lower Back Region Is a Common Problem Faced by ICU Nurses

The interview results from head nurses indicate that low back pain is a common complaint among ICU nurses. All eight head nurses and deputy head nurses stated that "The

TABLE 3 | Overview of the informants' characteristics.

Characteristics	n (%)
Gender	
Female	18 (100.0)
Age (years)	
≤ 30	1 (5.5)
31–40	10 (55.5)
41–50	7 (38.9)
Position	
Nurse manager	8 (44.4)
Bed-side nurse	10 (55.6)
Education	
Bachelor's degree	6 (33.3)
Master's degree	12 (66.7)
Experience in ICU (years)	
1–5	1 (5.6)
6–10	5 (27.8)
11–15	5 (27.8)
16–20	3 (16.7)
More than 20 years	4 (22.1)
Professional nursing title	
Primary	1 (5.5)
Middle	12 (66.7)
Advanced	5 (27.8)

TABLE 4 | The categories and subcategories.

Themes	Sub-themes
1. Muscle fatigue and pain in the region of lower back and waist among ICU nurses	1. The issue of muscle fatigue and pain in the lower back region is a common problem faced by ICU nurses
	2. The delivery of bedside nursing care places ICU nurses at a significant risk of experiencing muscle fatigue and pain in the lower back region.
	3. A specific posture involve providing back tapping and turning poses a significant level of risk
	4. The transfer of a patient can easily lead to acute lumbar muscle injury
2. "Human" factor	1. ICU patients are often severely ill and have three or more catheters and tubes inserted into their bodies
	2. ICU nurses often need to maintain a non-neutral posture for most time of the shift
	3. The principles of human mechanics are not well applied in practice, especially among young nurses
3. "Machine" factor	1. Lack of patient lifting system equipped
	2. The current ergonomic equipment and tools are insufficient to meet clinical needs and the functions also fall short of clinical requirements
4. "Environment" factor	1. Hospitals' healthy workplace culture is flawed
5. "Human-machine-environment" factor: interactions and relationships	1. The lack of healthy nursing operating procedure

majority of nurses in our department complain of significant lower back pain, with a percentage that should exceed 70%". The long-term accumulation of muscle fatigue is a key reason for this pain. "During busy periods, you have to work eight consecutive shifts, and the feeling of soreness and pain in the lower back was really suffering. After work, when you went back home, your kids were still clamoring to be carried, which exacerbates the pain" (H 08). "Now I don't know why there are so many severely ill patients waiting to be cured. I have 20 beds here, and they are fully occupied throughout the year. There is never a vacancy. During the New Year's holiday, when other healthcare colleagues go back home to celebrate the festival, the ICU units becomes even busier. After a normal shift, we are truly exhausted, both physically and mentally" (H 02). During the interview with the charge nurses, 6 out of 10 nurses (60%) reported non-specific discomfort, numbness, and pain in their lower back without any other conditions such as injury to the spine or spinal cord inflammation. In addition, two nurses (20%) reported severe lumbar disc herniation, indicating a serious occupational lumbar pain issue among ICU nurses. "I have been suffering from back pain for several years. It started at the third year of my current job.

Last year, I couldn't bear it anymore and I had to ask for a month-long sick leave..." (N 6).

4.1.2 | The Delivery of Bedside Nursing Care Places ICU Nurses at a Significant Risk of Experiencing Muscle Fatigue and Pain in the Lower Back Region

The results of interviews with ICU nursing managers and charge nurses indicate that the delivery of bedside nursing care by the ICU charge nurses poses a high risk for lower back injuries. "In

our ward, there are various positions with distinct responsibilities, including the charge nurse, preparationary nurse, general affairs nurse and clerical nurse. The charge nurses, on the day shift, are responsible for the care of two patients, while at night, they take care of four. According to the job requirements, the charge nurses must perform various routine nursing tasks, including morning nursing care, night care, catheter nursing care, turning and back massage, bed changing, intravenous infusion, insertion of vascular catheters, airway care, suctioning and along with monitoring of patients' conditions, providing health education and documentation and so on. When patients' conditions worsen, immediate cooperation in rescue work is required, and corresponding first aid measures must be implemented, including chest compression and artificial respiration. These measures are crucial for saving lives, we have no other choice" (H 01, 02, 04, 05); "Our charge nurses' workload is exceptionally demanding, requiring a sustained state of heightened mental acuity. We are not accorded any respite during our shift, often necessitating a prolongation of our workday by half an hour or even longer to ensure the completion of our assigned tasks. Upon conclusion of our shift, we could aptly be described as being utterly exhausted. The only opportunity for us to take a seat is while completing nursing records. After our shift, we are unable to even fully straighten our backs" (H 01). "As part of my shift, I am accountable for the care and treatment of two patients who rely on ventilators. The responsibilities associated with their care are quite extensive, rendering almost no opportunities for me to take a break and stretch my back during the course of a typical workday (sigh)" (N 2).

4.1.3 | A Specific Posture Involve Providing Back Tapping and Turning Poses a Significant Level of Risk

Turning a patient and/or tapping a patient's back is a routine nursing operation in the ICUs, and it has a high frequency and significant physical exertion. This operation also poses a high degree of harm to the nurse's waist and back muscles due to the required posture. "In response to patients with abnormal increases in sputum secretion, we have adopted a sideways position and administered percussion on their backs to facilitate expectoration. Unfortunately, after just a few minutes of this procedure, we have experienced significant soreness in our waist area and have felt the urge to shout for help" (H 04); "Yes, and when our supervisor comes over, he criticizes us in person if he doesn't hear a loud sound of back patting, claiming that we aren't puting in enough effort" (H 07); "Currently, we are facing a shortage of clinical nursing staff. Patients need to be turned and have their backs patted every 2 h. Typically, two nurses are needed for this task, which takes 6–10 min each time. For critically ill patients, it may take even longer. The physical strain of twisting to pat the patient's back is exhausting for our nurses" (H 01).

4.1.4 | The Transfer of the Patient Can Easily Lead to Acute Lumbar Muscle Injury

A common cause of low back muscle injury among ICU nurses is transferring patients in and out of bed. Currently, manual lifting is used to assist critically ill patients, requiring excessive force. This greatly increases the risk of acute low back muscle injury,

resulting in chronic pain symptoms and recurrent episodes. "I once injured my right waist muscle while lifting a patient for examination. It was extremely painful at that time. I visited the emergency room, took over a month off work, and underwent physiotherapy and rehabilitation. Even now, I still frequently experience pain in my right waist" (H 01); "I also have a history of strained muscles and since then, the root cause of my back pain has remained..." (H 08); "The patients in our department are often in critical condition and require frequent CT examinations. Nearly every bed needs to be relocated once a day. During a night shift, I had to assist a patient weighing over 260 pounds with an acute brain injury. Due to the urgency of the situation, I inadvertently strained my waist while helping three other staff members move him. As a result, now I experience discomfort in my waist whenever the weather changes..." (H 02).

4.2 | "Human" Factor

4.2.1 | ICU Patients Are Often Severely Ill and May Have Three or More Catheters and Tubes Inserted Into Their Bodies

The severity of patient's condition, combined with the abundance of catheters, frequently leads nurses to assume harmful postures during morning care. "ICU patients often require a range of therapeutic drugs, including sedatives, analgesics, and antibiotics. These medications are typically administered through liquid lines, of which patients may have between 3 and 12. However, maintenancing these lines can be challenging for nurses, who must frequently bend over to clean and care for them. This can be physically demanding and may increase the risk of injury or discomfort for nursing staff" (H 07). "Some patients experience excessive phlegm and severe oral infections, making the cleaning process difficult and strenuous. Our nurses often spend 7 or 8 min, or even longer, twisting our bodies to ensure thorough cleaning. This can take a toll on our physical well-being, leaving us feeling exhausted and strained. Despite the challenges, we remain dedicated to providing the best care possible for patients, even if it means enduring discomfort and fatigue" (H 04).

4.2.2 | ICU Nurses Often Need to Maintain a Non-Neutral Posture for Most of Their Shift

The charge nurse noted that in order to prevent catheter dislodgement, they often have to adopt awkward postures. "Nurses must pay attention to every pathway, wire, and catheter when turning patients to avoid displacement. When they are highly concentrated, they may use unnatural postures and exert force to position patients satisfactorily..." (H 05). "Our charge nurses have to twist their waists to perform manual back-tapping, which leads to unbearable lower back pain..." (N1, N2, N8).

4.2.3 | The Principles of Human Mechanics Were Not Well Applied in Practice, Especially Among Young Nurses

The reason is that some young nurses are unaware of the basic principles of human mechanics. "When I was young, I really didn't

know that I needed to reduce the deviation of my body's gravity line when operating, so I often used a single leg to support my body while reaching for things at the head or foot of the bed, completely forgetting to take a step forward to the left or right" (H 04). "We need to tidy up wires, restraints, drainage bags under the bed, and various other items after changing the patient's pads, providing post-defecation care, and assisting with turning and coughing. As a result, we often work with bent backs, rushing to finish the job, and forgetting to protect ourselves properly" (H 03). "Now I often see our young nurses bending over to change drainage bags, unaware that they should squat down to lower their center of gravity" (H 06). The awareness of young nurses in applying the principles of ergonomics is not strong enough. "I feel that our young nurses really don't know how to conserve their strength. It's possible that they may think they are physically fit and haven't considered saving their energy to protect their waist? Don't understand" (N 06).

4.3 | "Machine" Factor

4.3.1 | Lack of Patient Lifting System Equipped

All participants reported that their department lacked a patient transfer system, resulting in all patient lifting and moving being done manually. "We have to manually move the patients (sigh), and we often need to ask the nursing assistants for help. When we encounter overweight patients, we even call for the attending physicians" (H 08, N 09, N 10). "Initially, patients were transported for examinations using a bed, but this frequently caused collisions and wear and tear, leading to frequent repairs and high maintenance costs. Our beds cost over 1 million yuan each, and with various attachments, bedside tables, and other expensive items, so we chose to manually carry the patients to a stretcher instead to prevent damage" (H 04). "In our department, we routinely place a full-cotton bath towel on each bed. The bath towel is approximately 1.4 m long and 80 cm wide. We position it horizontally on the bed so that when we turn or move the patient, two people can directly grab the four corners of the bath towel and exert force, which makes it much easier for us" (H 02). "If only there was lifting equipment installed attaching to the ceiling, it would be extremely beneficial" (N 05).

4.3.2 | The Current Ergonomic Equipment and Tools Are Insufficient to Meet Clinical Needs and the Functions Also Fall Short of Clinical Requirements

Regarding the vibration phlegm suction device, "There are only two vibration sputum suction machines in our department, and over 20 patients need to use them every day. Such equipment is simply insufficient" (H 05). "Additionally, the vibration frequency of the sputum suction device is too fast and the force is too strong, which makes many conscious patients reluctant to use it. They prefer manual back-tapping..." (H 03). Furthermore, the functions of beds cannot safely meet the self-protection needs of clinical workers. "Although all ICU beds are electric smart beds with adjustable heights, the actual range of adjustable is very limited, and does not fully meet our requirements' (H 01). ICU nursing managers are also seeking some equipment and devices to reduce the risk of occupational low back pain among nurses. To lessen the burden of

nurses when turning patients, I found some new products, such as automatic turning beds, and tried them out myself. When lying on it, I felt that the bed was tilted to one side and experienced a sense of weightlessness. When I was being turned over, I felt a moment of panic" (H 02). "We have also tried a self-care device for post-defecation, but it is not very user-friendly" (H 01).

4.4 | "Environment" Factor

4.4.1 | Hospitals' Healthy Workplace Culture Is Flawed

During interviews with charge nurses, they revealed that hospital occupational safety training is almost exclusively focused on preventing the spread of infectious diseases. They suggested that hospitals should establish dedicated departments to manage occupational low back pain among healthcare workers and create a healthy working environment. "During our new employee orientation, the hospital only provided a 1-h occupational safety training course, which mainly covers the importance of preventing needlestick injuries and the handling procedures in case of needlestick injuries" (H 03). "The occupational safety liaison in our department has no clue about what occupational low back pain is, making it impossible for her to provide training to other nurses" (H 04). "I have noticed that some other hospitals specifically recruit strong individuals to form a transportation team, mainly responsible for the transportation of ICU patients. Should we have such a team here in the future?" (N 04).

The hospital needs a standardised approach to correct working posture, and there is a lack of emphasis on preventing back pain. "I remember four years ago when our department underwent Joint Commission international accreditation for healthcare institutions, a German expert conducted an on-site training session on preventing occupational low back pain. He guided us on the correct approach for moving and lifting patients. That training format was great, but no similar training has been conducted since then (Pout)" (H 01); several respondents expressed dissatisfaction with the absence of promotional materials promoting proper posture for nursing work throughout the hospital. "It seems that there are no posters or brochures on promoting proper posture for nursing work in any area of our hospital" (H 02). "Last time when I was at Hopkins Hospital, I saw that their medical information system could directly connect to the internet, allowing access to educational videos, articles on preventive back pain. Unfortunately our Electric case management system doesn't have this function" (H 07).

4.5 | "Human-Machine-Environment" Factor: Interactions and Relationships

4.5.1 | The Lack of Healthy Nursing Operation Procedure

The current emphasis in nursing operation training at schools is on patient safety, including selecting the correct injection site, thorough disinfection, promoting patient comfort and successfully completing nursing tasks. However, the process does not explicitly specify the posture nurses should adopt during

procedures or which postures to avoid. "Recently, I reviewed our nursing textbook on the 'Position Change Method' and 'Patient Transportation Method', but neither mentioned the posture that should be adopted to protect the nurse's waist and back (H 05). 'Indeed…, I examined the operational process for oral care, and it didn't mention the operator' posture (H 02). I am wondering if we can modify the operation process? Should we specify that nurses can sit down when inserting catheters for patients, allowing them to use short stools? Perhaps in this way, they can avoid bending over, and also avoid the situation where they can't get up after squatting for a long time. Since repeated squatting is very unfriendly to their knee joints and often leads to damage" (H 04).

5 | Discussion

Through a series of interviews with the nurse managers and ICU nurses, we gained a deeper understanding of the unique characteristics and challenges of ICU nursing. One consistent complaint expressed by the majority of the nurses was backache and sore waist. Our findings also indicate that acute back and waist muscle injuries are relatively common among this group of healthcare professionals. Furthermore, almost everyone with a history of acute injuries has experienced pain recurrence, which can have a significant negative impact on their subsequent work. Given these findings, it is crucial to accelerate establishment of comprehensive intervention programs to prevent MFrNO among ICU nurses.

5.1 | The Problem of "Human" Factors Related to the Development of MFrNO in ICU Nurses' Waist and Back

Firstly, this study confirms that ICU nurses' knowledge and skills in preventing low back muscle fatigue require improvement, and that younger nurses demonstrate a limited application of ergonomic knowledge in their clinical practice, aligning with previous research findings (Abdollahi et al. 2020; Zamora-Macorra et al. 2019; Soroush et al. 2018). Secondly, patients admitted to the ICU are fully dependent in terms of self-care, often requiring multiple indwelling catheters, infusion access, monitor leads, pulse oximetry, and ventilator lines. This complexity poses significant challenges for nursing care.

With the advancement of critical care medicine, specialised ICU nursing is evolving rapidly. ICU nurses function both as users of advanced instruments and equipment and as frontline providers in patient rescue, managing a heavy workload throughout the year. Consequently, the physical demands on this team are significantly greater than those placed on nursing staff in general wards (Jocelyn Chew et al. 2018). Nevertheless, during operations, nursing staff often neglect proper posture and engage in high-risk behaviours, such as muscle strains, in an attempt to increase speed and efficiency. As a result, ICU nurses are at a higher risk of MFrNO and pain compared to general ward nurses. Given this situation, it is essential for ICU nurses, particularly young nurses, to master the knowledge and skills necessary for preventing muscle fatigue. ICU managers should place greater emphasis on developing continuing education and training programs. Many professionals have recognised this and developed Back School programs (BPS), which has been widely used in many countries (Hernandez-Lucas et al. 2024). BPS not only includes theoretical learning—such as lower back anatomy, ergonomics, and patient handling techniques—but also guides nurses in practical training. This helps them to practice proper sitting, standing and lifting postures, as well as strength and stretch trunk exercises. Through continuous learning and practice, nurses can enhance their knowledge and skills integrating proper posture and occupational safety concepts into their daily lives and work, which is crucial for preventing or alleviating lower back muscle fatigue (Al Johani and Pascua 2019). Moreover, BPS does not require expensive or complex technology, making it cost-effective and practical.

5.2 | The Problem of "Machine" Factors Related to the Development of MFrNO in ICU Nurses' Waist and Back

Interviews revealed that the lack of lifting equipment, the insufficient number of nursing aides, and the inability to meet clinical needs are significant obstacles preventing nurses from performing their duties safely. In 2015, the American Occupational Safety and Health Association has included musculoskeletal injuries associated with patient handling among the occupational hazards (Kucera et al. 2019). The importance of rational equipment use in ensuring the safety of nurses during patient handling is clear. All ICU beds in this institution are equipped with adjustable height features, enabling nurses to modify the bed height according to their needs. Although, none of these beds have an automatic turning function, this height adjustment still nicely reduces the frequency and degree of bending required. Besides, there is a growing level of biomechanical evidence to support the use of assistive devices for many patient-handling tasks, which can help reduce the risk of MFrNO among care workers. For example, air-assisted devices have been shown to effectively reduce the biomechanical load on caregivers by circulating low-pressure, high-volume air through thousands of micro-perforations to decrease friction. But these devices are resrticted to repositioning and lateral transfers (Hwang et al. 2020). Additionally, mechanical ceiling lifts have proven effective in reducing biomechanical loading for all type of patient handling, including transfers, repositioning and lateral transfers (Fray and Davis 2024). Therefore, managers should focus on increasing the adoption of mechanisation, automation, and other auxiliary equipment to reduce the frequency of manual handling, turnover, and similar tasks. Meanwhile, they should strengthen education and training on the proper use of this equipment.

We acknowledge that costs may limit investment in tools designed to protect employees' occupational health. However, some nursing managers have proactively sought ways to save labor through manual lifting, achieving some success. For example, the routine allocation of bath towels for each bed unit allows nurses to save effort when changing a patient's position; when a bath towel becomes contaminated, they can simply replace it instead of changing the entire sheet, thereby reducing their workload. Alternatively, transfer boards and slides can

be used; these are low-cost options but require more human effort to operate and are only effective during lateral transfers (Sivakanthan et al. 2021).

5.3 | The Problem of "Environment" Factors Related to the Development of MFrNO in ICU Nurses' Waist and Back

Through interviews, we found a lack of training on safe postural practices and insufficient promotion of MfrNO prevention in this hospital organisation. This omission can be attributed to the limited emphasis on this area in traditional medical education, which consistents with previous studies (Abdollahi et al. 2020; Hu et al. 2022; Gilchrist and Pokorná 2021). As more and more countries recognise that nurses are one of the occupations with the highest risk of low back pain (Lee and Lee 2017), the important role of a healthy operational climate in ensuring safe nursing practice for nurses is receiving increased attention.

Firstly, it is evident that the attitude and support of managers play a pivotal role in fostering a robust safety culture (Bezzina et al. 2023). Secondly, the high intensity of work in ICUs may pose a challenge to establishing a healthier work atmosphere. High levels of nurse work fatigue and low job satisfaction are strongly associated with MFrNO, indicating that managers should attach great importance to the characteristics of "human" and ensure adequate staffing as much as possible. If human resources are limited, a humanistic shift management strategy is needed. Thus, to provide nurses with a conducive work environment, managers should attach importance to psychosocial factors (such as work pace, stree and burnout), not only prioritise patient safety but also consider the occupational health of nurses (Abdul Rahman et al. 2017; Al Johani and Pascua 2019; Liu et al. 2023).

5.4 | The Problem of "Human-Machine-Environment Interaction" Factors Related to the Development of MFrNO in ICU Nurses' Waist and Back

This study has confirmed that the specific nursing operation procedures do not explicitly specify the postures that operators should adopt or avoid during specific operation steps, leading to some confusion among clinical nurses. While nursing textbooks in China have already addressed the occupational health of nurses, there are still gaps in knowledge regarding how to prevent MFrNO, reduce muscle fatigue accumulation, and alleviate back pain. More evidence-based research is needed to obtain scientific evidence. In previous sections, we explored the problems and possible recommendations for improvement regarding human, machine, and environmental factors. But the occurrence of occupational low back pain is not a function of a single factor, as previous reviews (Sepehrian 2024) have shown: Managers should implement evidence-based, multi-component interventions at the organisational level in order to establish effective occupational health and safety measures that minimise the risk of low back injury among healthcare professionals. Therefore, Safe operating procedures, developed through an in-depth understanding of the hospital environment and with

consideration for the occupational health of nursing staff, will yield greater clinical significance. Based on this, we make the following recommendations: (1) In order to help identify potentially critical situations and develop tailored intervention measures for preventing MnFro, managers should actively using MAPO method to asses and evaluate risks during patient manual handling. This approach defines on the basis of factors like work organisation, average frequency of handling, type of patients, equipment, environmental conditions and the training of the operators and has been widely used in many countries with the advantages of simple and rapid operation. But it is rarely used in China (Kgakge et al. 2024; Cantarella et al. 2020). (2) Establishing a three-grade prevention system for MnFro in ICU, including primary prevention (focused on protecting healthy people from the possibility of becoming ill or suffering an injury), secondary prevention (aiming to early diagnosis and action once the first signs of the diseases have appeared) and tertiary prevention (aiming to manage long-term health problems). Take, for example, a series of studies by Soler-Font et al. (2024) in Spain on multifactorial workplace interventions to prevent work-related musculoskeletal pain. The primary prevention consists of participatory ergonomics training and healthy lifestyles. Secondary and tertiary prevention were formed by a case management service. Case managers can adopt different management and treatment strategies for nurses according to the risk level of musculoskeletal symptoms, so as to reduce the duration of sickness absence, musculoskeletal symptoms, and improve work continuity. This new paradigm may provide ideas for optimising the existing prevention and management model of MFrNO. Meanwhile, the specific intervention measures at each grade can be flexibly adjusted based on the hospital's existing prevention resources and the nurses' needs (Soler-Font et al. 2024; Serra et al. 2019; Soler-Font et al. 2019).

5.5 | Study Limitations

This study has the following limitations that should be addressed. Firstly, based on convenience sampling, we only interviewed ICU nursing managers and clinical nurses from a single comprehensive hospital, without including interviewees from multiple centers. However, our interviewees were selected from the five ICU units established by the hospital, including the central ICU and four specialised ICUs. Additionally, the institution is a regional medical center, and its ICU facilities, conditions, and management are all in the leading position nationwide, so the results of this study still offer valuable insights. Secondly, this study employed a semi-structured interview approach, and no quantitative data were collected using questionnaires or other methods. Future studies could consider addressing this shortcoming.

6 | Conclusions

This study, based on the theory of human-machine-environment, has conducted an in-depth analysis of the current state of ICU nurses' waist and back muscle fatigue from the perspectives of working posture and load factors. Our findings indicate that a significant proportion of nurses report

experiencing waist and back fatigue and pain. Among different job positions, charge nurses are at the highest risk. Younger nurses often show limited application of ergonomics knowledge in their daily practices. ICU nurses are frequently required to adopt harmful postures, such as forward body tilt combined with twisting. Factors that contribute significantly to waist and back muscle fatigue among ICU nurses include the absence of safe operating procedures, a lack of healthy work culture, inadequate lifting equipment, and insufficient auxiliary back support equipment.

Author Contributions

Yuting Yang: conceptualization, resource, visualisation, validation, writing – original draft. **Jing Li:** conceptualization, visualisation, investigation, writing – original draft, writing-review and editing. **Honghong Wang:** conceptualization, validation, methodology. **Yangyang Liu:** formal analysis, investigation. **Xuxin Wang:** formal analysis, investigation. **Su'e Yuan:** conceptualization, methodology, supervision, project administration and funding acquisition, writing – original draft, writing – review and editing.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Research data are not shared.

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Supporting Information

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