
Review article

ERGONOMIC STRATEGIES TO REDUCE MUSCULOSKELETAL DISORDERS IN NURSES: SYSTEMATIC REVIEW

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Abstract

Introduction: Nurses are at high risk of musculoskeletal disorders (MSDs). Ergonomic interventions, exercise, and workplace strategies may reduce this risk. This study aimed to identify effective interventions for preventing and managing MSDs and musculoskeletal pain (MSP) among nurses using ergonomic approaches.

Methods: A systematic review of PubMed and CINAHL studies was conducted according to PRISMA guidelines. Randomized and quasi-randomized controlled trials evaluating ergonomic approaches were included and assessed using the Cochrane RoB2 tool.

Results: Several ergonomic and multicomponent interventions were associated with reduced MSP and/or risk indicators among nurses. Educational, exercise, physiotherapy, and CBT components improved posture, strength, and functional outcomes in some studies, although effects varied by setting, intervention type, and measured outcomes. Mechanical lifting devices and digital exercise support were linked to reduced manual handling demands, lower pain and fatigue, and improved perceived safety.

Discussion and conclusion: Evidence suggests ergonomic education, structured exercise, and multicomponent workplace programs may reduce MSP and improve physical and psychosocial outcomes among nurses, although findings were heterogeneous. Technological aids may reduce workload and improve safety during patient handling. Small samples, heterogeneous interventions, and short follow-up limit generalizability, highlighting the need for larger trials.

Keywords: *Ergonomic interventions; Musculoskeletal pain; Nursing staff; Workplace strategies*

INTRODUCTION

Musculoskeletal pain and work-related musculoskeletal disorders are highly prevalent among nursing staff due to patient handling, repetitive tasks, and sustained awkward postures, representing a major cause of reduced work ability, sickness absence, and disability (Krishnan et al., 2021; Mitseas et al., 2023; WHO, 2022). In this review, the term musculoskeletal pain (MSP) refers to pain symptoms, whereas musculoskeletal disorders (MSDs) denote clinically or work-related diagnosed conditions. These problems can be a leading cause of disability, either resulting from work-related accidents or directly caused by occupational strain, which also entails sig-

nificant financial consequences (Cezar-Vaz et al., 2023).

Although various preventive measures exist, their implementation in clinical practice remains challenging. Effective prevention and management of musculoskeletal disorders among nursing staff often require multicomponent interventions tailored to specific work tasks, organizational contexts, and existing equipment (Rasmussen et al., 2022; Serra et al., 2019; Sousa et al., 2023). In response to this need, workplace interventions have been developed to reduce biomechanical load, alleviate MSP, and support nurses' ability to remain at work (Sepehrian et al., 2024).

Ergonomic interventions aim to optimize the fit between job demands and workers'

physical capabilities by improving work techniques, work organization, and the use of assistive devices, thereby reducing biomechanical strain and the risk of work-related MSDs (CDC and NIOSH, 2024). These approaches are frequently combined with structured exercise programs and psychosocial components, such as CBT, to address both physical and psychosocial risk factors associated with MSP (Albanesi et al., 2022; Stevens et al., 2019).

Previous studies suggest that participatory ergonomics, physical exercise, and cognitive-behavioral techniques (CBT) may be particularly relevant for preventing and managing low back pain (LBP) and other MSD-related outcomes among nursing staff (Russo et al., 2021; Stevens et al., 2019). However, existing evidence is heterogeneous in terms of intervention components, duration, and outcome measures, and results across studies are not always consistent. This variability highlights the need for a systematic synthesis of high-quality evidence focusing specifically on ergonomic approaches in nursing populations.

Therefore, the aim of this systematic review was to identify and synthesize evidence from randomized and quasi-randomized controlled trials (RCTs) on the effectiveness of ergonomic interventions in preventing and managing musculoskeletal disorders and pain among nursing staff. The research question guiding this review was: Which interventions are most effective in preventing and managing musculoskeletal disorders and pain among nursing staff through the application of ergonomic approaches?

MATERIALS AND METHODS

Following PRISMA guidelines, a systematic literature review was conducted to gather and analyze relevant studies from PubMed and CINAHL databases. Diagram 1 presents the PRISMA flowchart, illustrating the selection process of articles for this review. The following search strategy was used: (“nursing” OR nurs*) AND (musculoskeletal OR pain) AND (prevent* OR management OR control OR avoidance OR intervention* OR exercise OR

effect*) AND (ergonomics OR ergonomology OR ergonomic OR “ergonomic approach”). The literature searches were carried out on August 20, 2025.

The inclusion criteria required randomized and quasi-randomized clinical trials that focused on the prevention and management of musculoskeletal disorders and pain among nursing staff through the implementation of ergonomic approaches. RCTs were included because they provide the highest level of evidence and are considered the gold standard (Fernainy et al., 2024). The exclusion criteria included studies that were thematically irrelevant, as well as article types such as qualitative research, duplicates, editorials, protocols, and non-peer-reviewed contributions. Study selection and data extraction were conducted independently by two reviewers. Disagreements were resolved through discussion and, when necessary, by consensus with a third reviewer. The systematic literature review was limited to studies published in English, with no restrictions applied to the publication period. Included RCTs were assessed using the revised Cochrane Risk of Bias Tool for Randomized Trials (RoB2) (Sterne et al., 2019). Items from the checklist were judged as having a low risk of bias, some concerns, or a high risk of bias. Total scores were used to grade the methodological quality of each study. Due to heterogeneity in intervention components and outcome measures, results were synthesized narratively and reported by intervention category.

RESULTS

Study selection

As shown in Diagram 1, a total of 55 articles relevant to the research topic were identified through searches in the PubMed and CINAHL databases. The search results were exported to the EndNote X21 software, and duplicated studies were removed using this software. Eight articles were excluded as duplicates, and 22 were excluded based on the exclusion criteria. A total of 25 full-text articles were analyzed, of which 16 were included in the systematic literature review.

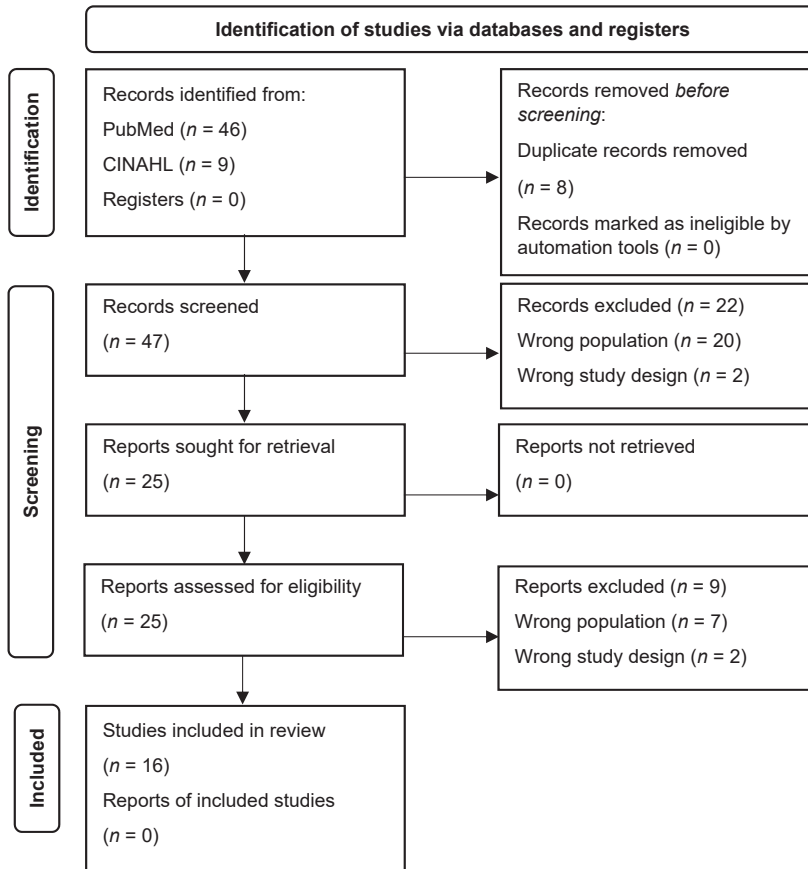


Diagram 1 – Flow chart based on the PRISMA methodology

Study characteristics

The main characteristics of the included RCTs are summarized in Table 1. Table 1 provides detailed information on country of origin, nursing role, and clinical setting for all included RCTs.

Across the 16 included RCTs, study populations varied substantially by nursing role and setting. Participants included registered nurses in specialized units (e.g., hemodialysis and operating rooms) (Abdollahi et al., 2020; Lee et al., 2024; Moazzami et al., 2015), hospital nursing assistants (Moreira et al., 2021; Menzel et al., 2006; Yassi et al., 2001), and nurse aides working in eldercare/long-term care settings (Rasmussen et al., 2015, 2016; Stevens et al., 2019).

Among the included RCTs, four were conducted in Denmark (Rasmussen et al., 2015, 2016; Stevens et al., 2019; Warming et al., 2008), two in Spain (Soler-Font et al., 2019,

2021), and two in Iran (Abdollahi et al., 2020; Moazzami et al., 2015), while one study each was conducted in Taiwan (Lee et al., 2024), Brazil (Moreira et al., 2021), the United States of America (Menzel et al., 2006), Canada (Yassi et al., 2001), Germany (Ewert et al., 2009), Hungary (Jaromi et al., 2012), Turkey (Akyurek et al., 2022), and Israel (Ratzon et al., 2016).

Sample sizes ranged from 30 to 594 participants (Akyurek et al., 2022; Rasmussen et al., 2015, 2016). Intervention duration varied considerably, from 6-week (Jaromi et al., 2012; Moazzami et al., 2015) programs to multifaceted interventions lasting up to 12 months (Soler-Font et al., 2019, 2021), with follow-up periods differing across studies. Outcomes included MSP intensity (e.g., LBP), prevalence of MSDs, physical workload, postural risk (e.g., REBA scores), functional capacity, fatigue, and QoL (Table 1).

Table 1 – Characteristics of the included RCTs studies

Author (Year) and Country	Population & setting (role/unit)	Interventions	Duration/follow-up	Main findings
Abdollahi et al. (2020) Urban area of Iran	n = 37 nurses and nurse assistants; operating rooms	Group ergonomic education: Educational informational materials and a 2-hour lecture delivered over 3 consecutive days on ergonomic principles, occupational stress, MSDs, the prevalence and risk factors of work-related MSDs among nursing staff, and methods for their prevention. Individual, face-to-face ergonomic education every 2 weeks based on direct observation and video-recorded work activities. Video-based feedback was used to identify ergonomic strengths and weaknesses during operating room tasks. Encouragement to apply ergonomic principles during daily work activities.	12 weeks (assessments every 2 weeks; end-of-study comparison).	The ergonomics educational program significantly reduced the overall risk of MSDs, with marked reductions observed in the ankle, hand/wrist, lower back, neck, hip, and shoulder.
Akyurek et al. (2022) Turkey	n = 30 general hospital nursing staff; hospital setting	WHPP: twice weekly for 35–40 min. of physical exercise combined with ergonomic education: Breathing exercises (5 min): equal breathing and abdominal (diaphragmatic) breathing. PMR (20 min): systematic contraction and relaxation of major muscle groups (feet, legs, hips, abdomen, chest, back, shoulders, arms, hands, neck, and face), with each 5-second contraction followed by 10 seconds of relaxation. Posture exercises (10 min): two strengthening exercises targeting the deep cervical flexors and shoulder retractors, and two stretching exercises targeting the cervical extensors and pectoral muscles. Ergonomic education: instruction on proper sitting posture, appropriate chair adjustment, and joint energy conservation techniques, as well as educational materials and illustrated exercise instructions for physical exercise at the workplace and at home.	5 weeks intervention + 12-month follow-up.	PMR, posture and breathing exercises, and ergonomic suggestions as part of the WHPP (relaxation and breathing exercises, correct posture exercises, ergonomic education, and targeted activities to improve Pro-QoL) resulted in a decrease in pain, fatigue, and stress levels, as well as an increase in coping skills and Pro-QoL.

Table 1 (continued)

Author (Year) and Country	Population & setting (role/unit)	Interventions	Duration/follow-up	Main findings
Ewert et al. (2009) Germany	<i>n</i> = 169 hospital and long-term care nurses with history of LBP; hospital setting	<p>A General Physical Exercise Program: 12 strengthening exercises targeting all major muscle groups (trunk, gluteal muscles, back, and lower limbs). Five exercises were performed without equipment, five using medical training equipment, one with free weights (5–15 kg dumbbells), and one using a lifting box with progressive load increases of 5 or 10 kg. Each strengthening exercise was followed by a stretching exercise lasting 10–20 seconds. Each session concluded with 12 minutes of low-impact aerobic exercise and relaxation exercises. A home-based exercise program including strengthening and stretching exercises was also prescribed. Additional components included stretching exercises, relaxation sessions, brief education on back care, swimming exercises, and low-impact aerobic exercise.</p> <p>A Multimodal Program: segmental stabilization exercises performed twice daily for 5–10 minutes (both during supervised training sessions and independently), aimed at improving lumbopelvic stability through the simultaneous activation of local stabilizing muscles (the multifidus muscle, transversus abdominis, and pelvic floor muscles), and integrating these exercises into daily activities.</p> <p>Ergonomic and workplace-specific exercise-related components: training in proper lifting techniques, work-related postures, and the safe use of assistive devices.</p> <p>Psychological components: support for adherence to physical exercise, stress management, and pain coping strategies.</p>	12-month intervention and follow-up (post-intervention assessment at 12 months).	Exercise Program (stretching and strengthening) and the Multimodal Program (exercise combined with CBT and ergonomic education) effectively reduced pain intensity and improved functional outcomes.
Jaromi et al. (2012) Hungary	<i>n</i> = 124 general nursing staff with chronic LBP; hospital setting	<p>Ergonomics education.</p> <p>Spine training programme "Back School" (50 min): practical training in correct posture (10 min), and therapeutic strengthening and stretching exercises (20 min) targeting the trunk and postural muscles. The exercises were performed both at the workplace and at home, and participants were encouraged to practice them regularly.</p> <p>Passive physiotherapy: electrotherapy, heat therapy, massage, and passive mobilization.</p>	6-week intervention; follow-up at 6 months and 12 months.	Passive physiotherapy and ergonomics education combined with active spine training programme ("Back School") once a week for 6 weeks resulted in a statistically significant reduction in LBP intensity compared to baseline. The active back therapy group showed significantly greater improvements, with superior outcomes at both the six-month and one-year follow-up assessments.

Table 1 (continued)

Author (Year) and Country	Population & setting (role/unit)	Interventions	Duration/follow-up	Main findings
Lee et al. (2024) Taiwan	n = 34 hemodialysis nurses; hemodialysis unit	Classroom-based education supported by video-based demonstrations: risk factors for work-related MSDs, ergonomic principles, improper working postures, and correct patient handling, lifting, and carrying techniques. Physical exercise: daily muscle-relaxing stretching exercises (10 min) and strengthening exercises performed every other day (15 min) targeting the neck, shoulders, upper and lower back, wrists/hands, hips, knees, and ankles/feet, conducted both at the workplace and at home. Use of equipment: elastic resistance bands (TheraBand®) and grip-strengthening balls.	12-week intervention; 12-week follow-up.	The exercise program supported by a messenger application can contribute to a reduction in work-related MSDs (degree of musculoskeletal discomfort in the elbows, wrists/hands, knees, and ankles/feet) and an improvement in muscle strength.
Menzel et al. (2006) United States of America	n = 86 registered nurses and nursing aides; rehabilitation hospital	CBT with standardized written materials and tapes: (1) relaxation techniques and progressive muscle relaxation; activity-rest cycles; (2) engagement in pleasant activities; time management distraction techniques, cognitive restructuring; (3) mini-relaxation on the job, on-the-job stress management, management and resolution assertiveness training; (4) communication skills, problem-solving skills, and (5) education on sleep hygiene, nutrition, and physical exercise. Ergonomic interventions (1 hour): (1) an assessment of the need for ergonomic equipment and assistive devices within the facility; (2) provision of ergonomic equipment and assistive devices (powered stand-assist devices, full-body sling lifts, full-body support lifts that do not require slings, stretchers that can be converted into chairs, and friction-reducing devices); (3) Training of proper use and application.	CBT: 6 weeks (6 x 1.5 h sessions); ergonomic intervention: subsequent 6 weeks; total study duration ≈12 weeks; monitoring every 2 weeks over 14 weeks; no long-term follow-up.	CBT alone did not lead to overall improvements but was effective in areas where pain most affected daily life (e.g., work, household tasks, social activities). Ergonomic intervention significantly improved VAS pain unpleasantness, while combined interventions (CBT + ergonomic) produced significant improvements in pain intensity, pain unpleasantness, and selected PDI subscales (self-care and life support), with large effect sizes.
Moazzami et al. (2015) Iran	n = 82 operating room nurses	Ergonomics-based education: focused on ergonomically correct working posture to prevent LBP in the operating room, aimed at changing behaviours related to work posture and promoting the proper use of body mechanics during nursing care activities.	4-week TTM-based ergonomics education (four 60-minute sessions); assessments at baseline, 1 month post-intervention, and 6 months post-intervention.	Ergonomics-based education in proper work-related posture for the prevention of LBP in the operating room contributes to the prevention of pain, especially chronic LBP.

Table 1 (continued)

Author (Year) and Country	Population & setting (role/unit)	Interventions	Duration/follow-up	Main findings
Moreira et al. (2021) Brazil	n = 90 nursing assistants; hospital	Therapeutic exercise program (twice weekly, 30 minutes per session): (1) warm-up exercises (5 minutes); (2) therapeutic exercises (20 minutes) focusing on trunk control through isometric contractions (curl-up, bird dog, cat-camel, and prone bridge exercises for lumbar spine stabilization), as well as anti-gravity exercises involving eccentric and concentric contractions to strengthen trunk flexor muscles and back extensors; (3) hamstring stretching and cool-down exercises (5 minutes) at the end of each session.	12 weeks, twice weekly, 30 minutes per session; outcomes were measured before the program (baseline) and immediately after the 12-week intervention period, no longer-term follow-up.	The therapeutic exercise program for spine stabilization, included warm-up and cool-down exercises, significantly increased trunk flexor strength, improved the pressure pain threshold of the dorsal longissimus, and reduced low back symptoms.
Rasmussen et al. (2016) Denmark	n = 594 nurse aides; elderly care / long-term care	Participatory ergonomics: focused on development of solutions for prioritized physically demanding work tasks and preparation of an implementation plan with the possibility of subsequent adjustments; the solutions were implemented in practice. CBT (two 3-hour workshops): improving understanding of pain, pain experience, and pain anticipation through cognitive exercises addressing the relationship between physical activity, physically demanding work, and pain; maintaining functional ability and a good QoL despite pain (i.e., pain coping, promotion of health-related behaviours, and adaptation of acquired skills to everyday life). Physical training: body awareness and body postures, strength and coordination training, general physical activity.	12-week intervention; follow-up assessments every 3 months (up to 15 months total), with additional pre-post intervention measurements.	The combined CBT and participatory ergonomics demonstrated a significant reduction in occupational lifting and a significant improvement in two measures of fear avoidance.
Rasmussen et al. (2015) Denmark	n = 594 nurse aides; elderly care / long-term care	Participatory ergonomics: focused on prevention of physical exertion and pain through minimizing risk factors for LBP at work and reducing or changing the work tasks perceived as physically demanding. CBT: with an emphasis on modifying maladaptive pain-related behaviours and cognitive processes. Physical training: focused on body awareness and posture, strength and coordination training, and general physical activity.	12-week intervention; monthly outcome assessments across ≈15 months, with primary effects evaluated 3 months post-intervention.	Participatory ergonomics, physical training, and CBT for LBP were effective, resulting in reductions in LBP days, LBP intensity, and bothersome days.

Table 1 (continued)

Author (Year) and Country	Population & setting (role/unit)	Interventions	Duration/follow-up	Main findings
Ratzon et al. (2016) Israel	n = 33 nurses with reported MSP; wards: delivery/labour, nephrology, NICU, internal medicine, surgery, oncology, ICU	Structured, personalized ergonomic program: (1) structured interview to identify the most physically demanding work task; (2) photographic documentation of the task during performance; (3) analysis of work posture and movements with the participant using an observational method before and after the ergonomic intervention. Segmental stabilizing exercises: exercises individually tailored based on reported pain and common work situations.	3-month intervention; outcomes assessed 6 months after start (≈3 months post-termination).	The intervention group that participated in a structured, personalized ergonomic program and segmental stabilizing exercises, showed a statistically significant improvement in REBA scores and body posture related to MSD risk factors compared to the control group that received only written instructions.
Soler-Font et al. (2019) Spain	n = 473 nurses and nursing aides; hospital units with high physical demand (direct patient care)	Participatory ergonomics: ergonomics training, identification and prioritization of ergonomic risks at the unit, development of proposed preventive measures, and implementation of organizational, technical, structural, and educational improvements in the workplace. Healthy lifestyle promotion: Nordic walking, mindfulness, and a healthy Mediterranean diet. Tailored case management: early detection of disabling musculoskeletal conditions (MSP and/or MSDs) and support for return to work.	12-month intervention; outcomes assessed at baseline, 6 months, and 12 months.	The implementation of participatory ergonomics, healthy lifestyle promotion activities, and case management resulted in a statistically significant reduction in the risk of neck, shoulder, and upper back pain.
Soler-Font et al. (2021) Spain	n = 257 nurses and nursing aides; hospital units with high physical demand (direct patient care)	Participatory ergonomics: self-completed questionnaire about MSP and exposure to musculoskeletal risk factors at work, identifying problems, proposing solutions and prioritizing them, execution of preventive measures (technical, structural, and organizational improvements in the workplace and training/information). Healthy lifestyle promotion program: Nordic walking, mindfulness, and a healthy Mediterranean diet. The tailored case management program: early detection of disabling musculoskeletal conditions (MSP and/or MSDs) and support for return to work (rehabilitation, medical consultation, CBT, and adjustments to job tasks or workplace adaptations).	12-month intervention; process indicators monitored during implementation; satisfaction assessed at 12 months; qualitative evaluation post-intervention.	Participatory ergonomics, physical activity, and the promotion of healthy lifestyle behaviors demonstrated positive effects in reducing MSP and improving functional capacity, with significant reductions in the prevalence and intensity of LBP and other musculoskeletal complaints. Participatory ergonomics was particularly effective, as it directly reduced physical workload during nursing tasks.

Table 1 (continued)

Author (Year) and Country	Population & setting (role/unit)	Interventions	Duration/follow-up	Main findings
Stevens et al. (2019) Denmark	n = 420 nurses and nurse aides; elderly care	Participatory ergonomics: workshops focused on reducing physical exertion at work by modifying the work tasks perceived as physically demanding and preventing pain by minimizing exposure to risk factors for LBP – implementation of the ideas presented in the workshops in the workplace. CBT: workshops focused on the use of cognitive processes to modify maladaptive pain behaviors and thus prevent/reduce pain and the negative effects of pain (problem solving and pain coping). Physical training (1 hour per week): various types of physical activity (body awareness/postural training, strength and coordination training, or general physical activity).	3-month intervention; monthly outcome assessments; mediators assessed every 3 months; repeated measurements across stepped-wedge trial (≈18 months total).	Participatory ergonomics, physical training, and CBT showed no significant indirect effects on reducing LBP; however, the level of physical exertion at work had a significant effect on LBP intensity.
Warming et al. (2008) Denmark	n = 181 nurses; surgical, gerontopsychiatric, internal medicine, geriatric wards	Transfer technique education: two trained nurses from each ward transferred the acquired knowledge and practical skills to their colleagues on the ward. Patient transfer technique: knowledge of transfer and movement assistance, including keeping the back in a vertical and neutral position, using the legs for weight transfer, and adjusting the working height. Physical fitness training: aerobic fitness training (e.g., running on a treadmill, cycling, skipping) and strength training (with a focus on the trunk and gluteal muscles) for 1 hour twice per week.	Transfer technique education: ≈12-week workplace programme; outcomes assessed at baseline, 6 months, and 12 months (primary follow-up).	The intervention showed little or no effect on LBP outcomes at follow-up (no statistically significant relationship between-group differences reported).
Yassi et al. (2001) Canada	n = 346 nurses and unit assistants performing patient lifts/transfers; medical, surgical, rehab wards	New mechanical patient lifting and transfer equipment, including mechanical total body lifts, sit-stand lifts, and a set of sliding devices. Intensive, problem-based, hands-on training in back care and patient handling techniques, including practical training in the use of available equipment (3 hours): (1) transfers from bed to chair or from chair to bed performed using sliding devices and a pushing technique; (2) training in the use of sliding devices for repositioning patients higher in bed and for turning patients from side to side; (3) training in the use of a transfer belt during patient ambulation.	Baseline + follow-ups at 6 and 12 months; injury outcomes monitored for 12 months.	The use of mechanical patient lifting and transfer devices significantly reduced manual lifting, largely replacing manual patient handling. Participants reported less fatigue, reduced back and shoulder pain, decreased overall discomfort, and an increased sense of safety when handling patients.

Note: MSDs – Musculoskeletal Disorders; REBA – Rapid Entire Body Assessment; CBT – Cognitive-Behavioural Training; WHPP – Workplace Health Promotion Program; PMR – Progressive Muscle Relaxation technique; Pro-QoL – Professional Quality of Life; LBP – Low Back Pain; PDI – Pain Disability Index; VAS – Visual Analog Scale; ≈ – approximately; MSP – Musculoskeletal Pain; ICU – Intensive Care Unit; NICU – Neonatal Intensive Care Unit

Risk of bias assessment (RoB 2) of included RCTs

Table 2 summarizes the key results on ergonomic approaches to reducing MSDs and pain in nursing staff and presents the quality

assessment of the included RCTs. Three studies (Ewert et al., 2009; Menzel et al., 2006; Moreira et al., 2021) were rated as having a low risk of bias.

Table 2 – Quality of the evidence of the included RCTs studies

Author (Year)	Quality of the evidence					
Participants	D ₁	D ₂	D ₃	D ₄	D ₅	O
Abdollahi et al. (2020)	–	+	+	+	+	–
Akyurek et al. (2022)	+	–	+	–	+	–
Ewert et al. (2009)	+	+	+	+	+	+
Jaromi et al. (2012)	–	+	+	+	–	–
Lee et al. (2024)	–	+	+	–	–	–
Menzel et al. (2006)	+	+	+	+	+	+
Moazzami et al. (2015)	–	–	+	–	–	–
Moreira et al. (2021)	+	+	+	+	+	+
Rasmussen et al. (2016)	–	+	+	+	+	–
Rasmussen et al. (2015)	–	+	+	+	+	–
Ratzon et al. (2016)	–	+	+	+	–	–
Soler-Font et al. (2019)	–	+	+	+	+	–
Soler-Font et al. (2021)	–	+	+	+	+	–
Stevens et al. (2019)	–	–	+	–	+	–
Warming et al. (2008)	–	–	–	+	+	–
Yassi et al. (2001)	–	+	+	+	+	–

Note: D – Domains; O – Overall; D₁ – Risk of bias arising from the randomization process; D₂ – Risk of bias due to deviations from the intended interventions (effect of assignment to intervention); D₃ – Missing outcome data; D₄ – Risk of bias in measurement of the outcome and D₅ – Risk of bias in selection of the reported result; – Some concerns; + Low risk

Effects of interventions

As shown in Table 1, the results indicated that several ergonomic and multicomponent interventions were associated with reductions in MSP and/or risk indicators, although effects were heterogeneous across studies and outcomes.

Ergonomic educational programs focused on improving nurses' knowledge of ergonomic principles, correct body posture, and safe patient handling techniques were consistently associated with reductions in musculoskeletal risk (Abdollahi et al., 2020) and improvements in pain unpleasantness (Menzel et al., 2006). While Warming et al. (2008) reported overall limited effects on LBP outcomes,

with no consistent reduction in pain indicators across groups. Educational interventions delivered through lectures, demonstrations, written materials, or video-based feedback increased awareness of work-related risk factors and promoted safer work behaviors, resulting in reduced MSD prevalence across multiple body regions (Abdollahi et al., 2020; Lee et al., 2024), including the lower back (Moazzami et al., 2015), as well as the neck, shoulders, and upper limbs (Abdollahi et al., 2020). In contrast, Warming et al. (2008) reported little or no effect on LBP outcomes.

Structured and personalized ergonomic programs were characterized by individualized assessments of work tasks (Ratzon et

al., 2016), systematic analyses of posture and movement patterns (Moazzami et al., 2015), and the development of tailored ergonomic solutions adapted to nurses' specific job demands (Soler-Font et al., 2019). These interventions typically incorporated observational methods, photographic or video analyses (Ratzon et al., 2016), and direct feedback to identify high-risk tasks and modify work techniques accordingly (Soler-Font et al., 2019). Such personalized approaches led to significant improvements in work-related posture, reductions in biomechanical risk factors, and lower musculoskeletal risk scores, particularly when combined with task-specific exercises or participatory implementation strategies (Moazzami et al., 2015; Ratzon et al., 2016; Soler-Font et al., 2019).

Active and passive physiotherapy interventions included therapeutic exercise, spine training programs (e.g., "Back School"), and passive physiotherapy modalities such as massage, heat therapy, electrotherapy, and ultrasound. Physiotherapy-based approaches were more effective when active components were emphasized. Programs combining ergonomic education with active spine training demonstrated greater and more sustained reductions in LBP intensity compared with passive physiotherapy alone, highlighting the added value of exercise-based rehabilitation (Jaromi et al., 2012).

Physical exercise, including spinal stabilization, strengthening, stretching, and general physical activity, was associated with improvements in physical capacity and reductions in musculoskeletal symptoms among nursing staff. Exercise-based programs focusing on trunk stabilization and muscle strengthening contributed to increased muscle strength, improved functional capacity, and reduced LBP intensity, particularly when exercises were performed regularly and integrated into the workplace setting (Ewert et al., 2009; Moreira et al., 2021). Such interventions were associated with reductions in musculoskeletal discomfort across multiple body regions and improvements in functional outcomes beyond pain reduction alone (Lee et al., 2024). However, evidence from transfer-technique instruction combined with physical fitness training was mixed, with Warming et al. (2008) reporting little effect on LBP outcomes.

Combined programs incorporating CBT, participatory ergonomics, physical training, and health promotion activities demonstrated beneficial effects on both physical and psychosocial musculoskeletal outcomes among nursing staff. Interventions integrating participatory ergonomics with CBT and physical training were associated with reductions in pain intensity and frequency (Rasmussen et al., 2015; Stevens et al., 2019) and fewer days with MSP (Rasmussen et al., 2016). In addition, WHPP or healthy lifestyle promotion and ergonomic interventions that integrated physical activity, relaxation techniques, or organizational-level changes contributed to reduced physical workload (Soler-Font et al., 2021), decreased fatigue and stress (Akyurek et al., 2022), improvements in pain-related beliefs (Soler-Font et al., 2019, 2021), and improved functional outcomes and professional QoL (Akyurek et al., 2022). Overall, these findings indicate that multicomponent interventions addressing both biomechanical and psychosocial risk factors are more effective than single-component approaches in managing MSDs among nursing populations.

The use of technology and digital support interventions included the use of exercise-support applications (Lee et al., 2024), mechanical patient lifting and transfer devices, and assistive equipment aimed at reducing physical workload (Yassi et al., 2001). These interventions were associated with significant reductions in manual handling demands, MSP, and fatigue, as well as improved perceived safety during nursing tasks (Yassi et al., 2001). The introduction of mechanical lifting devices substantially decreased exposure to high-risk patient handling activities (Yassi et al., 2001), while digital tools supported exercise adherence and symptom management (Lee et al., 2024). Evidence regarding job satisfaction is limited, as this outcome was not consistently assessed in the included trials.

DISCUSSION

This review examined the effectiveness of ergonomic interventions in preventing and managing MSDs and pain among nursing staff. Five main categories of interventions were identified: ergonomic educational programs, active and passive physiotherapy,

physical exercise, combined programs (including CBT, participatory ergonomics, and health promotion), and the use of technology and digital support.

Interpretation of the findings should consider contextual differences across countries, healthcare systems, and nursing roles. For example, RCTs in Danish eldercare settings largely targeted nurse aides exposed to frequent patient handling and high physical demands, which may favor multicomponent workplace approaches addressing both biomechanical and psychosocial risk factors (Rasmussen et al., 2015, 2016; Stevens et al., 2019; Warming et al., 2008). In contrast, studies conducted in specialized hospital units (e.g., hemodialysis and operating rooms) involved different exposure profiles such as prolonged standing, constrained postures, and repetitive upper-limb tasks, potentially influencing which ergonomic and exercise components are most effective (Abdollahi et al., 2020; Lee et al., 2024; Moazzami et al., 2015). Moreover, intervention dose and follow-up duration varied widely – from short programs (approximately 6 weeks) to interventions lasting up to 12 months – which likely contributed to heterogeneity in outcomes and may partly explain why some trials demonstrated short-term improvements while longer-term effects remain uncertain (Jaromi et al., 2012; Moazzami et al., 2015; Soler-Font et al., 2019, 2021; Yassi et al., 2001). Study-specific implementation factors (e.g., access to lifting equipment, training intensity, workplace support, and adherence to exercise) may further affect effectiveness across settings (Lee et al., 2024; Soler-Font et al., 2019, 2021; Yassi et al., 2001).

It should also be acknowledged that cultural and organizational differences across countries may have influenced the effectiveness of ergonomic interventions. Studies conducted in Scandinavian countries (e.g., Denmark) were largely embedded in occupational settings where participatory and multicomponent workplace programs were implemented, which may favor such approaches (Rasmussen et al., 2015, 2016; Stevens et al., 2019; Warming et al., 2008). In Scandinavian countries, occupational health systems are characterized by strong regulatory frameworks, employer responsibility for workplace health, and established traditions of participatory ergonomics and prevention, which may facil-

itate the implementation of multicomponent workplace interventions (OSHwiki, 2019, 2020). In contrast, studies conducted in hospital settings in Asia or the Middle East more often evaluated individual-level education or exercise-based programs (Abdollahi et al., 2020; Lee et al., 2024; Moazzami et al., 2015). These contextual differences, together with variation in intervention duration and follow-up, should be considered when interpreting the heterogeneity of outcomes (Jaromi et al., 2012; Soler-Font et al., 2019, 2021; Yassi et al., 2001).

Ergonomic educational programs consistently demonstrated a reduction in the overall risk of MSDs and improvements in body posture (Abdollahi et al., 2020; Moazzami et al., 2015; Ratzon et al., 2016). This is consistent with the findings of Demir and Yilmaz (2024), who recommend that ergonomic programs be incorporated into in-service training for nurses.

Active and passive physiotherapy showed greater benefits when combined with active back therapy and ergonomic education (Jaromi et al., 2012). Physical exercise, particularly spine stabilization and strengthening programs, enhanced muscle strength, reduced symptoms, and improved functional capacity among nursing staff (Ewert et al., 2009; Moreira et al., 2021). For instance, in the RCT by Moreira et al. (2021), a workplace-based therapeutic exercise program delivered twice weekly (30 minutes per session) resulted in significant increases in trunk flexor strength, an improved pressure pain threshold of the dorsal longissimus, and reduced LBP among nursing assistants. Similarly, Ewert et al. (2009) reported that both exercises alone and a multimodal intervention (exercise combined with ergonomic/workplace-specific training and CBT) produced clinically meaningful reductions in pain intensity and improvements in functional outcomes in nurses with LBP. In addition, exercise embedded within broader workplace programs showed benefits beyond pain outcomes; for example, Lee et al. (2024) found that an ergonomic training program supported by a messenger application, including regular stretching and strengthening exercises, was associated with reduced musculoskeletal discomfort (e.g., elbows, wrists/hands, knees, and ankles/feet) and improved muscle strength, while evidence from trans-

fer-technique instruction combined with physical fitness training was mixed, with Warming et al. (2008) reporting little effect on LBP outcomes. Collectively, these trials provide specific evidence that regular, structured exercise – particularly when combined with ergonomic education and workplace-specific training – contributes to reducing MSD-related symptoms and improving function, thereby supporting occupational health promotion among nursing staff (Sousa et al., 2023).

Combined programs incorporating CBT, participatory ergonomics, and health promotion activities appeared beneficial in several trials, not only in reducing pain intensity and frequency but also in improving psychosocial well-being and QoL (Akyurek et al., 2022; Rasmussen et al., 2016). These findings support the value of comprehensive biopsychosocial interventions as essential for the effective prevention and management of MSDs in healthcare settings (Sousa et al., 2023).

Technological and digital solutions, including patient lifting and transfer devices as well as exercise-support applications, were associated with reductions in physical workload, pain, and fatigue, as well as improved perceived safety during nursing tasks (Lee et al., 2024; Yassi et al., 2001). Evidence regarding job satisfaction is limited, as it was not consistently assessed as a primary outcome in the included trials. A scoping review suggests that technology use may help reduce nurses' workload, although evidence is heterogeneous (Mohammadnejad et al., 2023).

Research findings indicate that multicomponent interventions tailored to the specific demands of nursing work are more effective than single-component approaches. However, small sample sizes, heterogeneity of interventions, and short follow-up periods, in addition to variations in the methodological quality

of RCTs, may limit the generalizability of the findings and highlight the need for larger and methodologically robust RCTs.

CONCLUSION

A systematic literature review has shown that ergonomic approaches (the adaptation of workstations, the use of ergonomic equipment, and training on proper posture and lifting techniques) may reduce workload and improve working conditions among nursing staff, particularly when implemented as part of comprehensive, multicomponent programs. Successful implementation therefore requires comprehensive ergonomic training programs that include workplace modifications, the use of ergonomic devices, and the promotion of ergonomics, thereby achieving long-term improvements and reducing the burden of MSDs and pain among nursing staff.

Study limitations

Due to the exclusive focus on randomized and quasi-randomized controlled trials, only a limited number of studies were eligible for inclusion. In addition, the literature search was restricted to PubMed and CINAHL; therefore, relevant studies indexed in other databases may have been missed. The review protocol was not registered in PROSPERO prior to study initiation, which may increase the risk of selective reporting. Nevertheless, the review followed PRISMA guidelines, applied predefined eligibility criteria, and used a structured and transparent study selection process.

Ethical aspects and conflict of interest

The authors have no conflict of interest to declare.

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