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Review article

Nursing interventions for people with musculoskeletal injuries during physical activity: A scoping review

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ABSTRACT

Introduction: Physical inactivity is a major public health concern, with Portugal ranking among the European countries with the lowest levels of regular physical activity. Poorly managed physical activity is associated with a high incidence of musculoskeletal injuries, increasing the need for effective nursing interventions focused on prevention, rehabilitation, and safe return to activity. In orthopedic and trauma care, nurses play a key role in clinical assessment, patient education, functional recovery, and interdisciplinary coordination; however, nursing-specific interventions in this area remain insufficiently mapped.

Objective: To map the scientific literature on nursing interventions for individuals with musculoskeletal injuries related to physical activity.

Method: A scoping review was conducted following the Joanna Briggs Institute methodology, guided by the PCC framework: Population (individuals with musculoskeletal injuries), Concept (nursing interventions), and Context (physical activity). Searches were performed in MEDLINE Ultimate, CINAHL Ultimate, SPORTDiscus, Psychology and Behavioral Sciences Collection, and Scopus, complemented by grey literature. Studies published in English, Portuguese, Spanish, or French were included. Study selection and data extraction were conducted independently by two reviewers, following PRISMA 2021 guidelines.

Results: 36 studies were included. Most originated from the United States and Europe, and were situated within medicine, physiotherapy, and rehabilitation sciences. Nursing-relevant interventions included comprehensive clinical assessment, pain management, health education, psychosocial support, multidisciplinary rehabilitation coordination, therapeutic exercise guidance, balance and proprioception training, activity modification, and reinjury prevention.

Conclusion: The evidence highlights multiple nursing interventions applicable to musculoskeletal injury rehabilitation of individuals with physical activity, reinforcing the importance of nurses within orthopedic and trauma care.

1. Introduction

Physical activity plays a crucial role in promoting health and the prevention of non-communicable diseases. It is currently recognized as a determinant of health (DGS, 2021). Globally, around 31 % of adults have insufficient levels of physical activity, according to data from the World Health Organization (WHO, 2024). This scenario is also reflected in the European context. According to a study in the European Union, adults do not meet the minimum recommended levels of physical activity, highlighting the high prevalence of sedentary behaviours among the population (Nikitara et al., 2021).

According to the "Global Action Plan on Physical Activity 2018–2030" (WHO, 2018), the primary general goal is to create active societies, environments, individuals, and systems. The strategic plan includes interventions based on health education, as well as the integration of physical activity into health services, implemented strategically to reverse the trend of increasing sedentary behaviour (WHO, 2018). Several countries have adapted these guidelines to their contexts. In Portugal, the Directorate-General for Health (DGS) has defined physical activity as a priority health programme, acknowledging that

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few behavioural health interventions offer as many benefits across multiple domains as physical activity (DGS, 2021).

Despite the numerous benefits associated with physical activity, it is not without risk. Musculoskeletal injuries may result from physical activity, exercise, and/or sports practice, and their incidence is significant among both beginners and regular practitioners. Physical activity is classified into three levels of intensity (light, moderate, and vigorous), reflecting the degree of effort required. This classification not only guides appropriate exercise prescription but is also directly related to its musculoskeletal health implications. Different intensity levels can yield various benefits or, in some cases, increase the risk of injury, particularly when not properly monitored and tailored to individual capabilities. Therefore, understanding and applying this classification is particularly important when planning public health promotion programmes, as highlighted by the World Health Organization (WHO, 2020).

Caring for individuals with musculoskeletal injuries means recognizing the possibility of limitations in functional capacity and active citizenship, with direct impacts on physical and mental well-being. Musculoskeletal injuries related to physical activity may hinder its continuity, especially when associated with pain and functional limitations (Cai et al., 2020a, 2020b). The vulnerability linked to routine changes caused by injury may significantly reduce activity levels, fostering more sedentary lifestyles (Barchek et al., 2020; Martins et al., 2021).

Musculoskeletal injuries have gained prominence in discussions surrounding physical activity, both in professional sports and recreational contexts. Recent literature reflects growing concern over their association with decreased physical activity and the health and well-being implications for individuals. One relevant aspect explored in research is the association between overtraining and locomotor system injury risk, emphasizing the importance of accurate diagnosis and adapted training programmes to mitigate such risks (Sieńko-Awierianów and Chudecka, 2020).

Understanding the dynamics of musculoskeletal injuries and their consequences is essential for developing effective interventions for both prevention and rehabilitation. Current literature offers a broad perspective on epidemiology, injury types, and risk mitigation strategies, reflecting the complexity of the topic (de Sire, 2022; Dijksma et al., 2020; Gimigliano et al., 2021). Additionally, prevalence rates vary widely depending on the sport, age group, and level of practice and/or competition, highlighting the need for context-specific approaches (Cai et al., 2020a, 2020b; Costa e Silva et al., 2022; Kemler et al., 2022; Martins et al., 2021). Sports participation during childhood proves beneficial for general health but also poses a higher injury risk, mainly due to growth-related musculoskeletal changes, rendering young athletes more vulnerable (Costa e Silva et al., 2022). Preventive measures such as pre-exercise warm-up and post-exercise stretching are therefore essential and should not be neglected.

Among adults, sports such as athletics, football, and martial arts show the highest injury incidence rates (Gimigliano et al., 2021). The same study notes that musculoskeletal injuries represent one of the main health concerns among professional athletes, significantly affecting performance and quality of life.

With an estimated 5.8 million acute injuries treated annually in emergency departments across the European Union, the study by Kemler et al. (2022) indicates that novice individuals have significantly higher injury rates compared to experienced athletes. This data are crucial to understanding the impact of injuries on continued physical activity. Despite the well-documented public health benefits of physical activity, musculoskeletal injuries may hinder these gains, as pain and functional incapacity pose substantial barriers to physical activity adherence and continuity (Dijksma et al., 2020; Okobi et al., 2022).

In this context, nursing care for individuals with musculoskeletal injuries or at risk of developing them encompasses prevention to rehabilitation, including interventions such as detailed clinical assessment, accurate diagnosis, preventive education, individualized functional support, guidance on proper techniques, and gradual activity progression (de Sire, 2022; Heinert et al., 2021; Stathas et al., 2024).

These strategies are essential to minimize injury recurrence risk and promote a safe return to physical activity, preventing the adoption of sedentary lifestyles following functional impairment.

Given the diversity of injury types, the heterogeneity of populations and practice contexts, the absence of studies published by nurses on their interventions in this area and the broad range of nursing interventions reported in the literature, a scoping review is the most appropriate methodological approach. This design enables systematic mapping of available evidence, clarification of key concepts, identification of intervention characteristics, and detection of knowledge gaps that may inform future research and clinical practice.

Accordingly, the guiding research question is: “What nursing interventions are described in the scientific literature for individuals with musculoskeletal injuries related to physical activity?”

The objective of this review is to systematically map and characterize the nursing interventions reported for this population and context.

2. Methods

This scoping review was conducted in accordance with the Joanna Briggs Institute (JBI) methodology for scoping reviews, using the Population, Concept, Context (PCC) framework. The review focused on: (i) population, individuals with musculoskeletal injuries resulting from physical activity; (ii) concept, nursing and nursing-led interventions, with particular emphasis on rehabilitation approaches; and (iii) context, physical activity practice settings, including recreational exercise and sports environments.

The review is reported in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) (Tricco et al., 2018; Peters et al., 2022). Reporting of this scoping review followed the PRISMA-ScR guidelines, and a completed PRISMA-ScR checklist is provided as a supplementary file.

A review protocol was developed a priori and registered in the Open Science Framework (DOI: 10.17605/OSF.IO/V2WTA).

2.1. Eligibility criteria

In accordance with the PCC framework, the inclusion criteria were as follows: population including children, adolescents, adults, older adults, athletes and physically active individuals with acute or chronic musculoskeletal injuries related to physical activity or sport; concept corresponding to nursing or nursing-led interventions addressing prevention, rehabilitation, recovery, or safe return to physical activity and context consistent with recreational, occupational, military, or sports physical activity settings.

No restrictions were applied regarding study design or methodological quality. Eligible sources of evidence included quantitative, qualitative, and mixed-methods studies and reviews. Also, grey literature was included to identify relevant nursing evidence not indexed in traditional bibliographic databases. No initial date limits were imposed to ensure comprehensive mapping of nursing-led interventions. Studies published up to December 31, 2024 were included. Publications written in English, French, Portuguese and Spanish were considered eligible.

2.2. Information sources and search strategy

The following electronic databases were searched from inception to December 31, 2024. Searches in MEDLINE Ultimate, CINAHL Ultimate, SPORTDiscus, and Psychology and Behavioral Sciences Collection were conducted via the EBSCOhost® platform on January 3, 2025, using the following strategy:

[(nurs* OR intervention*) AND (people OR child OR teenager OR adult OR elderly OR athlete* OR jock* OR sportsman OR “sport

player*") AND ("musculoskeletal injuries" OR "skeletal muscle injuries" OR "musculoskeletal system injur*")].

For Scopus, the strategy was adapted to controlled fields:

[(nurs OR "nursing intervention*" OR "rehabilitative nursing") AND (people OR child* OR teenager* OR adult* OR elderly OR athlete* OR sportsman OR "sport player*") AND ("musculoskeletal injur*" OR "skeletal muscle injur*" OR "musculoskeletal system injur*") AND ("physical activit*" OR exercise OR sport* OR "rehabilitation setting*")]. Boolean operators and truncation were applied to enhance sensitivity and reproducibility.

2.3. Grey literature search

A grey literature search was conducted to identify non-indexed evidence relevant to rehabilitation and nursing-led interventions for people with musculoskeletal injuries. The search was performed on January 3, 2025 using Google Scholar, conference proceedings platforms (e.g., Even3), and non-indexed open-access journals.

This approach ensured inclusion of sources not captured in traditional bibliographic databases. Search terms included combinations of rehabilitation interventions, nursing treatment, musculoskeletal injuries, and physically active populations. Terms were adapted to each platform, with the use of Boolean operators and truncation to maximize sensitivity and reproducibility. Two reviewers independently screened titles and abstracts, advancing all potentially relevant records, as well as any with reviewer disagreement, to full-text assessment. Discrepancies were resolved through discussion or, if necessary, consultation with a third reviewer. Full texts of records deemed potentially eligible were evaluated according to predefined inclusion criteria.

The study by Cavalcante and Almeida (2024) was identified through manual screening of conference proceedings hosted on the Even3 platform, while Rios et al. (2024) was retrieved via targeted searching for rehabilitation protocols in non-indexed journals. Both sources met the eligibility criteria and were classified as grey literature.

2.4. Study selection

All retrieved records were imported into the Rayyan® platform, where duplicates were identified and removed. Two reviewers independently screened titles and abstracts. Studies considered potentially

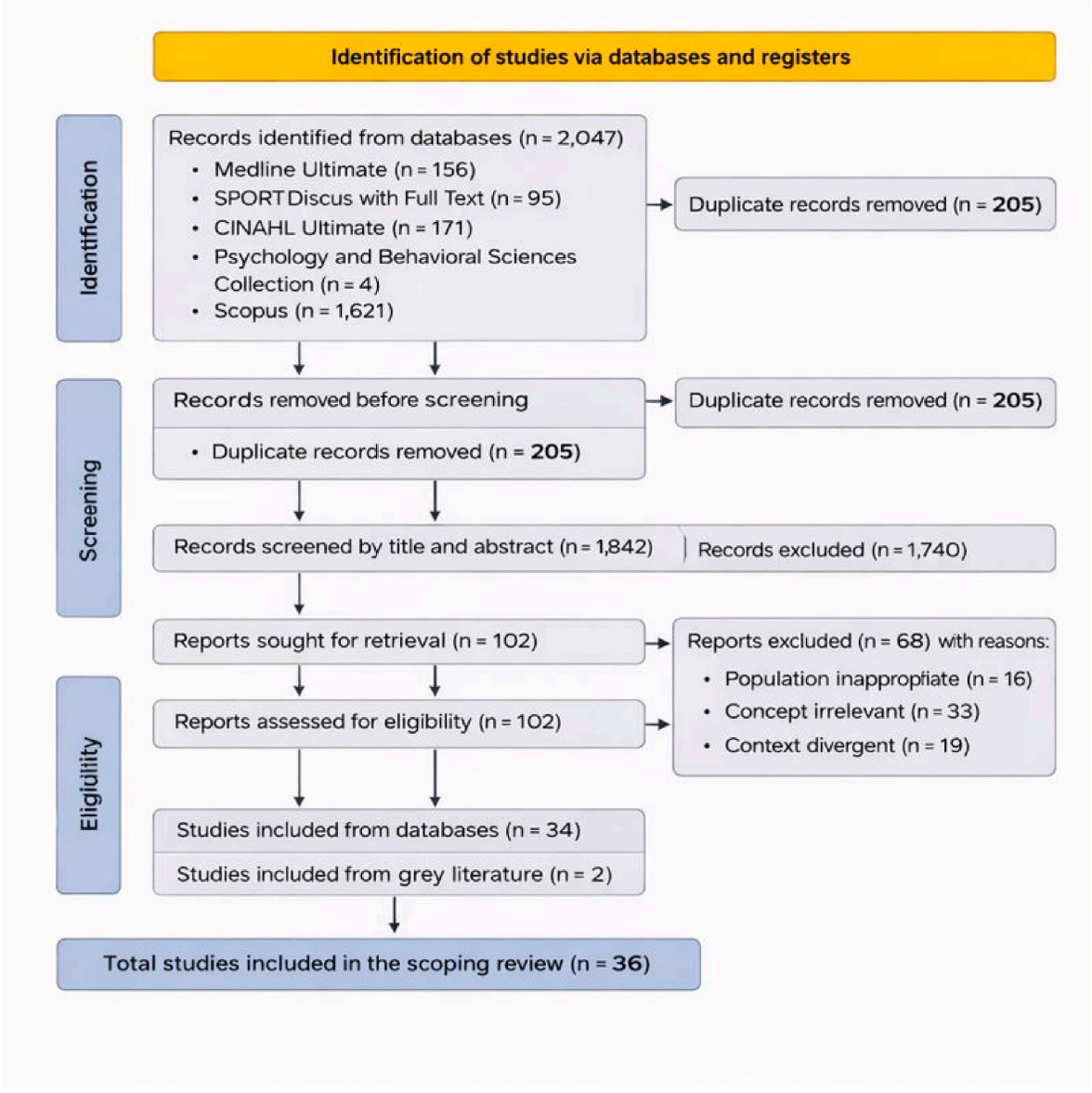

Figura 1. PRISMA 2021 flow diagram literature research results.

eligible, as well as records with reviewer disagreement, were advanced to full-text assessment. Full texts were independently evaluated by the same reviewers. Any disagreements were resolved through discussion and, when necessary, consultation with a third reviewer. Disagreements at any stage resulted in inclusion in the subsequent phase to minimize the risk of erroneous exclusion. The study selection process and reasons for exclusion were summarized using the PRISMA 2021 flow diagram (Page et al., 2021) (Fig. 1).

2.5. Source of evidence selection

Fig. 1 illustrates the identification, screening, eligibility, and inclusion processes for this scoping review. Initially, 2047 records were identified across five databases: Medline Ultimate (n = 156), SPORT Discus with full text (n = 95), CINAHL Ultimate (n = 171), Psychology and Behavioral Sciences Collection (n = 4) and Scopus (n = 1621). After removing 205 duplicate records, 1842 studies were screened by title and abstract, leading to the exclusion of 1740 articles.

Of the 102 articles evaluated in full text, 16 were excluded due to inadequate population, 33 were excluded due to irrelevant concept and 19 due to divergent context. Beyond the studies identified through electronic database searches, two pertinent grey literature sources were also incorporated, selected based on their relevance and methodological transparency, to provide a more comprehensive overview of existing evidence on rehabilitative nursing interventions for musculoskeletal injuries. Ultimately, 36 studies were included in the review. This process ensured transparency and reproducibility in the selection of sources of evidence and guided the subsequent data extraction, which was organized into tables for thematic analysis.

2.6. Data extraction and synthesis

Data extraction was conducted using structured forms developed by the research team. Charting was performed independently by two reviewers, with cross-checking to ensure accuracy and consistency. Extracted data were organized into tables to support descriptive and thematic synthesis.

The following variables were retrieved from each included source:

- Bibliographic data (author, year, country).
- Study design.
- Population characteristics.
- Description of rehabilitative nursing interventions.
- Context of physical activity practice.
- Outcomes or purpose of the intervention.
- Key findings relevant to the PCC framework.

No assumptions or simplifications beyond the predefined eligibility criteria were applied. In accordance with Joanna Briggs Institute guidance for scoping reviews, no critical appraisal of methodological quality was undertaken, as the purpose of this review was to map the breadth, characteristics, and nature of the available evidence rather than to evaluate study quality. A descriptive and thematic synthesis was conducted to identify intervention types, patterns, and contextual characteristics across the included sources.

3. Ethical considerations

Scientific literature reviews, regardless of the option, should present the state of knowledge to make it clear what the current knowledge is on the subject to be studied (Sousa et al., 2018; Nunes, 2020; Marques-Vieira et al., 2021). The review process must be rigorous, with intellectual honesty, and draw on a variety of sources. To this end, the authors used must be respected, both through correct referencing and through fidelity to the data collected, in compliance with the principle of academic integrity (Ana et al., 2013; Nunes, 2020; Marques-Vieira et al., 2021).

4. Results

A total of 2047 records were identified through database searching, including 426 records from the EBSCOhost® platform and 1621 records from Scopus. After removal of duplicates, titles and abstracts were screened, and potentially eligible records were assessed at full text. The study selection process and reasons for exclusion are presented in the PRISMA flow diagram (Fig. 1).

The inclusion of 36 studies in this scoping review ensured a more comprehensive and contemporary mapping of the available evidence on nursing interventions for people with musculoskeletal injuries. The included studies encompassed a wide range of study designs, including randomized controlled trials, quasi-experimental studies, prospective cohort studies, systematic and narrative reviews, case reports, integrative reviews, expert opinions, and conceptual papers. This methodological diversity reflects the exploratory nature of the scoping review and supports a broad understanding of rehabilitative nursing contributions within musculoskeletal care.

From a disciplinary perspective, the studies originated predominantly from medicine, physiotherapy, sports medicine, rehabilitation sciences, sports psychology, nutrition, and physical education, highlighting the inherently multidisciplinary context in which nursing interventions are delivered. Geographically, the evidence base spanned multiple regions, including Europe, North and South America, Asia, Australia, and Africa.

Across the included studies, rehabilitative interventions addressed both injury recovery and reinjury prevention, frequently combining physical, educational, and psychosocial components. Core intervention domains included therapeutic exercise (strength, balance, proprioception, flexibility, and aerobic conditioning), pain management strategies (manual therapy, electrotherapy, cryotherapy, shockwave therapy, taping, and heat modalities), health education (injury prevention, sleep, nutrition, activity management, and return-to-activity planning), and psychosocial support (management of kinesiophobia, emotional coping, motivation, and adherence to rehabilitation).

Populations ranged from youth, adult, and elderly athletes to military personnel and individuals with work-related or recreational musculoskeletal injuries, with activity intensities varying from light to high-impact sports participation. Collectively, the findings demonstrate that rehabilitative nursing interventions are embedded within complex, multimodal rehabilitation pathways, contributing to functional recovery, symptom management, safe return to activity, and long-term musculoskeletal health.

This expanded body of evidence provides a comprehensive foundation for thematic synthesis and underscores the relevance of rehabilitative nursing within multidisciplinary musculoskeletal injury management.

4.1. Study characteristics

The 36 studies included in this scoping review were published between 2006 and 2024, reflecting both foundational and contemporary evidence in musculoskeletal rehabilitation. The studies originated from a wide range of geographic regions, with the United States being the most represented country (n = 12) (Bellows and Wong, 2018; Catapano et al., 2022; Colgan et al., 2023; Gribble et al., 2023; Kivlan et al., 2015; McGuine and Keene, 2006; Montalvo et al., 2014; Needle and Howard, 2024; Rogers et al., 2013; Steere et al., 2021; Wideman and Sullivan, 2012; Young et al., 2023), followed by Brazil (n = 3) (Camargo et al., 2014; Cavalcante and Almeida, 2024; Rios et al., 2024). China, England, Indonesia, Iran and Spain each contributed two studies, while all remaining countries were represented by a single publication (Australia, Germany, Italy, France, Norway, Bulgaria, Japan, South Korea, India, Malaysia, Ethiopia).

Overall, the evidence base spanned Europe, North and South America, Asia, Africa, and Oceania, highlighting the international scope of rehabilitative practice in musculoskeletal injury care.

From a disciplinary perspective, the included studies were predominantly grounded in medicine (n = 10) (Booth-Kewley et al., 2009; Chennaoui et al., 2021; Coppack et al., 2016; Dedes et al., 2019; Petersen et al., 2013; Rosado-Velazquez et al., 2020; Shin et al., 2020; Steere et al., 2021; Tavakol et al., 2019; Vuletić and Bøe, 2024) and physiotherapy/physical therapy (n = 10) (Bellows and Wong, 2018; Camargo et al., 2014; Colgan et al., 2023; Pastora-Bernal et al., 2018; Rogers et al., 2013; Rios et al., 2024; Tejwani and Varadharajulu, 2024; Vittala et al., 2024; Wideman and Sullivan, 2012; Young et al., 2023). Additional contributions originated from sports medicine and sports sciences (n = 5) (Cavalcante and Almeida, 2024; Li et al., 2024; McGuine and Keene, 2006; Montalvo et al., 2014; Yalfani et al., 2024), rehabilitation/physiology (n = 8) (Catapano et al., 2022; Chen, 2024; Gribble et al., 2023; Hatta et al., 2018; Kivlan et al., 2015; Melese et al., 2020; Needle and Howard, 2024; Rossi, 2024), sports psychology (n = 1) (Liu and Noh, 2024), nutrition and dietetics (n = 1) (Alcock et al., 2024), and physical education (n = 1) (Ndayisenga et al., 2024). This distribution underscores the multidisciplinary context in which rehabilitative nursing interventions are developed and implemented, frequently intersecting with allied health and medical domains.

The populations studied were heterogeneous. Most studies focused on athletes and physically active individuals (n = 17) (Bellows and Wong, 2018; Camargo et al., 2014; Cavalcante and Almeida, 2024; Colgan et al., 2023; Hatta et al., 2018; Kivlan et al., 2015; Li et al., 2024; McGuine and Keene, 2006; Montalvo et al., 2014; Pastora-Bernal et al., 2018; Petersen et al., 2013; Rogers et al., 2013; Rosado-Velazquez et al., 2020; Tavakol et al., 2019; Vittala et al., 2024; Yalfani et al., 2024; Young et al., 2023), including youth, adults, and older athletes across recreational, competitive, and elite levels. Military personnel were represented in four studies (n = 4) (Booth-Kewley et al., 2009; Chennaoui et al., 2021; Coppack et al., 2016; Steere et al., 2021), while older adults and aging athletes were the primary focus in four studies (n = 4) (Catapano et al., 2022; Gribble et al., 2023; Melese et al., 2020; Vuletić and Bøe, 2024). One study addressed workers with work-related musculoskeletal injuries (n = 1) (Wideman and Sullivan, 2012). The remaining studies comprised reviews, conceptual frameworks, and expert opinions that addressed broader musculoskeletal populations without restricting inclusion to a specific age group or activity level (n = 10) (Alcock et al., 2024; Chen, 2024; Liu and Noh, 2024; Ndayisenga et al., 2024; Needle and Howard, 2024; Rios et al., 2024; Rossi, 2024; Shin et al., 2020; Tejwani and Varadharajulu, 2024; Dedes et al., 2019).

A wide range of study designs was identified, consistent with the exploratory aim of a scoping review. These included narrative reviews, integrative reviews, conceptual articles, and expert opinions (n = 12) (Alcock et al., 2024; Camargo et al., 2014; Cavalcante and Almeida, 2024; Catapano et al., 2022; Chennaoui et al., 2021; Liu and Noh, 2024; Needle and Howard, 2024; Rios et al., 2024; Rogers et al., 2013; Rossi, 2024; Steere et al., 2021; Vuletić and Bøe, 2024); systematic reviews and meta-analyses (n = 7) (Bellows and Wong, 2018; Li et al., 2024; Melese et al., 2020; Montalvo et al., 2014; Pastora-Bernal et al., 2018; Petersen et al., 2013; Shin et al., 2020); randomized controlled trials (n = 6) (Coppack et al., 2016; Gribble et al., 2023; Hatta et al., 2018; Kivlan et al., 2015; McGuine and Keene, 2006; Yalfani et al., 2024); quasi-experimental and controlled experimental studies (n = 4) (Chen, 2024; Dedes et al., 2019; Ndayisenga et al., 2024; Tejwani and Varadharajulu, 2024); prospective cohort or observational studies (n = 4) (Booth-Kewley et al., 2009; Catapano et al., 2022; Gribble et al., 2023; Wideman and Sullivan, 2012); and case reports or case studies (n = 3) (Rosado-Velazquez et al., 2020; Tavakol et al., 2019; Young et al., 2023). This methodological diversity reflects the complexity of musculoskeletal rehabilitation research and supports comprehensive mapping of rehabilitative nursing-relevant interventions rather than comparative effectiveness evaluation.

Of the sources included in this scoping review, the majority were peer-reviewed journal articles, with two sources classified as grey literature. These comprised one conference proceeding by Cavalcante and Almeida (2024) and one article published in a non-indexed open-access journal by Rios et al. (2024). Both sources focused on nursing-led or rehabilitation-oriented interventions targeting musculoskeletal injuries in physically active or athletic populations and met all predefined eligibility criteria. The inclusion of these sources contributed to a broader understanding of clinical rehabilitation practices not consistently represented in indexed nursing journals.

Across study designs and populations, interventions primarily targeted injury recovery, reinjury prevention, or both, frequently adopting multimodal approaches that combined therapeutic exercise, physical modalities, education, psychosocial support, and activity management strategies.

Detailed study characteristics and extracted variables are presented in Table 1.

4.2. Synthesis of results

4.2.1. Physical activity practice and intensity

Across the 36 included studies, physical activity was a central component of both rehabilitation and injury prevention, with type, intensity, and progression tailored to population characteristics, injury type, and recovery stage. Findings extracted from each study covered bibliographic details, sample characteristics, type and aims of intervention, physical activity context, nursing-relevant components, and reported outcomes.

A wide range of interventions was identified across physical, behavioural, and educational domains, including supervised exercise programmes, manual and adjunctive therapies, proprioceptive training, electrotherapy-based modalities, cryotherapy, hydrotherapy, neuromuscular training, neurofeedback, and health education strategies focused on pain, sleep, emotional regulation, and nutrition. Programs varied substantially in intensity, duration (1–32 weeks), and delivery mode, with many adopting progressive, multimodal rehabilitation approaches relevant to nursing practice. This variability was consistently linked to population characteristics, injury type, baseline functional status, and physical activity demands, rather than reflecting inconsistency in care delivery. More intensive and prolonged programs were typically implemented among athletes and military personnel, whereas older adults or more vulnerable populations received shorter or lower-intensity interventions. Collectively, these findings highlight individualization and progressive adaptation of physical activity as central components of musculoskeletal rehabilitation across settings, underscoring the key role of nursing in monitoring response to activity, guiding progression, and supporting safe, person-centered rehabilitation trajectories.

Structured therapeutic exercise was the core component in most studies, commonly combining strength, balance, proprioception, flexibility, and aerobic training, applied across athletic, military, and general musculoskeletal populations. Progressive strength and balance training was used in rehabilitation for athletes with ankle instability or lower-limb injuries (Bellows and Wong, 2018; McGuine and Keene, 2006; Yalfani et al., 2024), while similar components were adapted for military personnel (Coppack et al., 2016; Steere et al., 2021).

Aerobic activity was included as a standalone modality (walking, swimming, cycling, yoga) or within functional training programs. Low-impact aerobics were emphasized in older adults and aging athletes to support mobility and balance while minimizing injury risk (Catapano et al., 2022; Gribble et al., 2023; Rogers et al., 2013). Sport-specific physical practice was also described, reflecting real-world rehabilitation contexts and return-to-sport requirements (Chen, 2024; Hatta et al., 2018; Rosado-Velazquez et al., 2020; Vittala et al., 2024; Young et al., 2023).

Intensity ranged from light to high. Moderate-to-intense activity

Table 1
Data extraction table.

Author(s) Year Discipline Study/Title Country	Study Type	Objective	Population and Sample	Type of Physical Activity	Nursing Care Domain	Impact of Action (Prevention and/or Recovery)
Coppack et al. **2016** **Medicine** *A comparison of multidisciplinary team residential rehabilitation with conventional outpatient care for the treatment of non-arthritic intra-articular hip pain in UK military personnel - a protocol for a randomised controlled trial.* **England**	Randomised Clinical Trial (protocol)	To balance muscle strengthening with physical function recovery	100 male participants aged 18 to 50; Military personnel	Aerobic activity and strength exercises for upper and lower limbs Moderate to intense physical activity intensity.	Combined and progressive interventions over 6 weeks including: strength and balance training, flexibility exercises, hydrotherapy, manual therapy, health education: pain management, relaxation, behavioral therapy, nutrition, aerobic training, postural re-education, return to sports activity.	Injury recovery and reinjury prevention
Rosado-Velázquez et al. **2020** **Medicine** *Adductor longus injury after electromechanical self-treatment: A case report.* **Spain**	Case Study	To analyze the factors that contributed to the injury, the diagnostic methods used and the therapeutic approach.	27-year-old	Professional soccer Intense physical activity.	Combined and progressive interventions, over 4 weeks, which include: manual therapy, electrotherapy, cryotherapy, flexibility exercises, musculo-articular mobilizations, strength training, aerobic and balance training, postural re-education, return to physical activity: sports	Injury recovery and reinjury prevention
Rogers et al. **2013** **Physiotherapy** *Balance training for the older athlete.* **USA**	Narrative Literature Review	To evaluate the gains of sensorimotor training through progressive balance training for physical activity.	Elderly people	Aerobic activity: Intensity of physical activity: light to moderate;	A 12-week program of combined and progressive interventions that include: - Strength training. - Balance and coordination training.	Injury recovery and reinjury prevention.
Dedes et al. **2019** **Medicine** *Comparison of radial extracorporeal shockwave therapy versus ultrasound therapy in the treatment of rotator cuff tendinopathy.* **Bulgaria**	Controlled Experimental Study	To compares the effectiveness of radial extracorporeal shockwave therapy versus therapeutic ultrasound therapy in reducing pain and improving function in patients with rotator cuff tendinopathy.	61 adult patients diagnosed with rotator cuff tendinopathy and shoulder pain with functional limitation. Participants were treated in a rehabilitation setting and allocated to two intervention groups: 31 received radial extracorporeal shockwave therapy and 30 received therapeutic ultrasound.	Moderate-intensity functional physical activity	Intervention, for 4 weeks: - Electrotherapy (pain management; functional recovery support)	Injury recovery and reinjury prevention
Wideman and Sullivan **2012** **Physiotherapy** *Development of a cumulative psychosocial factor index for problematic recovery following work-related musculoskeletal injuries.* **USA**	Prospective Cohort Study	To evaluate the psychosocial factors that can influence recovery from musculoskeletal injuries in the workplace.	202 people with work-related musculoskeletal injuries.	Not specified Intensity of physical activity: light	Intervention, for 7 weeks: - Health Education: pain management; movement management and emotional management;	Injury recovery and reinjury prevention
Tavakol et al. **2019** **Medicine** *Effect of intensive neuromuscular electrical stimulation on chronic neck pain: A case report.* **Iran**	Case Study	Identifying the impact of electrotherapy on chronic neck pain in a 21-year-old female athlete.	21-year-old	Gymnastics Intensity of physical activity: intense;	Program of combined and progressive interventions, over 12 weeks, comprising: - Electrotherapy (3 sessions of intensive neuromuscular electrical stimulation, lasting 20 min and with	Injury recovery and reinjury prevention

(*continued on next page*)

Table 1 (*continued*)

Author(s) Year Discipline Study/Title Country	Study Type	Objective	Population and Sample	Type of Physical Activity	Nursing Care Domain	Impact of Action (Prevention and/or Recovery)
					a rest period of 48 h; based on tolerance. After treatment: resistance exercises (3 times a week for a minimum of 12 weeks) - isometric flexion exercises and dynamic resistance exercises;	
Chennaoui et al. **2021** **Medicine** *How does sleep help recovery from exercise-induced muscle injuries?* **France**	Narrative Literature Review	Highlight the impact of sleep on musculoskeletal injury recovery	Athletes and military personnel	Aerobic activity and strength exercises for upper and lower limbs Moderate to intense physical activity intensity;	Intervention over 1 week: - Health education: sleep and rest (sleep extension may potentially aid and/or prevent recovery from exercise-induced muscle injuries by improving local inflammation control)	Injury recovery and reinjury prevention
Colgan et al. **2023** **Physiotherapy** *Implementation of cognitive retraining to diminish kinesiophobia associated with chronic ankle instability: A case report.* **USA**	Case Study	Educate on resilience strategies to common psychological responses to musculoskeletal injuries, especially chronic ankle instability. Promote confidence and physical activity ability	28-year-old female	Aerobic activity Moderate physical activity intensity;	Combined and progressive intervention over 4 weeks including: active and resisted movements, strength training, balance and proprioception training, flexibility exercise, hydrotherapy, manual therapy, health education: pain management, behavioral therapy, aerobic training, localized postural re-education, physical activity planning/ management.	Injury recovery and recurrence prevention
Hatta et al. **2018** **Physiology** *Pilates exercise improves hip joint flexion mobility in rugby players.* **Japan**	Randomised Controlled Clinical Trial	Assess the relationship between improved hip flexion mobility and injury prevention in high-impact sports	30 rugby athletes	Aerobic activity and strength exercises for upper and lower limbs Intense physical activity intensity;	Combined and progressive intervention over 3 weeks including: Lower limb and core strength training; - Balance training; - Flexibility exercises; - Physical activity planning/management	reinjury prevention
Gribble et al. **2023** **Rehabilitation** *Yoga as a balance intervention for middle-age and older adults with history of lateral ankle sprain: An exploratory study.* **USA**	Prospective Cohort Study	Evaluate guidance on implementing yoga for balance training in individuals with ankle sprain history	13 adults aged 40–65 with prior lateral ankle sprain	Light physical activity intensity related to yoga;	8-week intervention program (1 h/week) including: breathing exercises, postural re-education and control, balance training, flexibility exercises, relaxation techniques, health education (relaxation strategies, injury prevention)	Injury recovery and reinjury prevention
Petersen et al. **2013** **Medicine** *Treatment of acute ankle ligament injuries: a systematic review.* **Germany**	Systematic Literature Review	Assess the effectiveness of non-surgical treatment for physically active individuals with ankle musculoskeletal injuries	Individuals aged 16 and above with musculoskeletal injuries	Aerobic activity: walking and swimming Light to moderate physical activity intensity;	Combined and progressive intervention program including: neuromuscular training, strength training, aerobic training, balance and proprioception training	Injury recovery and reinjury prevention
Bellows and Wong **2018** **Physiotherapy** *The effect of bracing and balance training on ankle sprain incidence among athletes: A systematic review with*	Systematic Review and *meta-analysis*	Evaluate the effectiveness of balance training and bracing in ankle sprains	High school and university athletes (with or without injury)	Moderate to intense physical activity related to basketball.	Use of devices: ankle stabilizers, health education: use of device, balance and proprioception training.	Recurrence prevention

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Author(s) Year Discipline Study/Title Country	Study Type	Objective	Population and Sample	Type of Physical Activity	Nursing Care Domain	Impact of Action (Prevention and/or Recovery)
meta-analysis. **USA**						
McGuine and Keene **2006** **Sports Medicine** *The effect of a balance training program on the risk of ankle sprains in high school athletes.* **USA**	Randomized Clinical Trial	To evaluate the effectiveness and impact of balance training in reducing the incidence of acute ankle sprains in secondary school athletes.	680 secondary school athletes	Basketball and soccer Physical activity: moderate to intense	Intervention, for 8 months: - Balance and proprioception training	Injury recovery and reinjury prevention
Catapano et al. **2022** **Rehabilitation** *The aging athlete.* **USA**	Mixed Study - Observational, Quasi-Experimental and Descriptive	Evaluate the effectiveness of interventions to prevent and treat injuries. Validate methods to increase the safety and performance of elderly athletes to maintain high levels of activity.	Elderly athletes aged 60 and over, physically active throughout their lives	Low-impact exercise, including walking, aquatic exercise and Static bicycle; Flexibility exercises Strength exercises in the MS and IM Physical activity: moderate to intense;	Combined intervention program: 30–60 min of moderate intensity resistance exercise in sessions of at least 10 min (150–300 min per week) - Flexibility exercises (cross-training with flexibility exercises, such as static stretching, at least 2 days a week); - Balance training; - Strength training (2 or 3 sets of one or two multi-joint exercises per main muscle group; weight 70 %–85 % of your one-repetition maximum, 2–3 times a week); - Health education: injury prevention; nutrition; - Physical activity planning/management; - Physical activity management in people with tendinopathy ("prehabilitation" with initial rest and activity management for 2–6 weeks; progress to eccentric exercises) - Management of bone stress injuries (prolonged rest, exercises without load; management of expectations and health education);	Injury recovery and reinjury prevention
Young et al. **2023** **Physiotherapy** *Successful physical therapist management of an ankle injury in the austere wilderness of denali: a case report.* **USA**	Case Study	Implement a multimodal treatment plan with exercises to strengthen and promote ankle stability	36 years old man with an ankle sprain injury	Climbing Physical activity: intense;	Combined interventions that include: - Musculo-articular mobilizations. - Manual therapy (stretching); - Strength training. - Flexibility exercises. - Advanced therapies: Neuromuscular bands. - Aerobic training - Balance training	Injury recovery and reinjury prevention
Booth-Kewley et al. **2009** **Medicine** *Psychosocial predictors of return to duty among marine recruits with musculoskeletal injuries.* **England**	Cross-sectional observational study	Exploring psychosocial factors and the management of expectations that affect recovery from injuries in military personnel	166 military personnel with musculoskeletal injuries, aged between 17 and 29	Aerobic activity and upper and lower limb strength exercises. Physical activity: moderate to intense;	Program of focused interventions: - Emotional support/ management. - Social/community support - Health education: support networks; multidisciplinary referral.	Injury recovery and reinjury prevention

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Author(s) Year Discipline Study/Title Country	Study Type	Objective	Population and Sample	Type of Physical Activity	Nursing Care Domain	Impact of Action (Prevention and/or Recovery)
Steere et al. **2021** **Medicine** *A narrative review evaluating extracorporeal shockwave therapy as a potential regenerative treatment for musculoskeletal conditions in military personnel.* **USA**	Narrative Literature Review	Identify efficacy of ESWT on lower extremity conditions	Physically active populations (including military, recreational and/or elite athletes);	Aerobic activity and strength exercises (lower extremity)	Program a minimum of three to five sessions once a week (however, 1 session may still be beneficial for a quick return to physical activity). - ESWT application with eccentric exercises - Rehabilitation divided into three phases that complement the three phases of tissue healing (inflammatory, proliferative and remodeling), including progression from isometric to eccentric strengthening and increased loading.	Injury recovery
Alcock et al. **2024** **Dietetics and Nutrition** *Youth and adolescent athlete musculoskeletal health: dietary and nutritional strategies to optimise injury prevention and support recovery.* **Australia**	Narrative Literature Review	Implement effective nutritional strategies for injury prevention, recovery and rehabilitation, improving long-term health and sports performance.	Youth and adolescent athlete	Physical activity: moderate to intense;	Nutrition (taking into account the stage of rehabilitation and the type of injury): - Macronutrient management (considering immobility after musculoskeletal injury; the metabolic needs of recovery; the rehabilitation phase; reactions to possible pain-relieving medications; appetite and the benefits for tissue repair). - Micronutrient management according to the type of injury (bone (bone deposition and mineralization, calcium absorption, bone renewal, calcium homeostasis, regulation of parathyroid hormone and activation of vitamin D), muscle (cellular energy, muscle repair and regeneration), connective tissue (collagen synthesis (healing ligaments, tendons, skin and muscle; prevents the risk of infection)) and the rehabilitation phase. - Supplementation management (analytically confirmed);	Injury recovery and reinjury prevention
Vuletic and Bøe **2024** **Medicine** *Considerations in the aging female athlete considerations in the aging female athlete.* **Norway**	Literature review	Understand the specific challenges faced by female athletes throughout their lives and the treatment strategies adapted to their specific injury and general state of health. Promote proactive strategies for	Aging Female Athlete	Low impact physical activity (swimming, cycling, strength training); physical activity: moderate to intense;	Combined interventions that include: - Body weight management - Diet control - Rest/rest management - Strength training - Personal protective equipment	Injury recovery and reinjury prevention

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Author(s) Year Discipline Study/Title Country	Study Type	Objective	Population and Sample	Type of Physical Activity	Nursing Care Domain	Impact of Action (Prevention and/or Recovery)
		maintaining musculoskeletal health.			Post-surgical interventions (serious injuries): - Strength and proprioception training - Gradual progression with sport-specific activities - Flexibility exercises - Balance training - Warm-up and return to calm	
Yalfani et al. **2024** **Sports science** *Neurofeedback training can increase the efectiveness of neuromuscular training on balance and limit of stability of athletes with chronic ankle instability: three arms and single-blind randomized control trial.* **Iran**	Randomized Controlled Clinical Trial	To investigate the effects of neurofeedback training combined with neuromuscular training compared to neuromuscular training alone in athletes with chronic ankle instability.	62 male athletes aged between 18 and 25 with chronic ankle instability who play tennis, badminton or table tennis. With a history of lateral sprain in the last year, with symptoms such as swelling, pain and temporary loss of physical activity.	Physical activity: moderate to intense	Combined and progressive interventions integrating neuromuscular training with 24 sessions over 8 weeks, with 3 sessions per week, each lasting 30 min: – 6 exercises following the principle of progressive overload, the level of exercise gradually increased (increase in the number of sets and duration of exercises each week). Neurofeedback training protocol with neuromuscular training lasting 30 min in addition to neuromuscular training (30 min) for 8 weeks, three sessions a week. After the neurofeedback training protocol, the subjects performed neuromuscular training. Integration of proprioception, balance and sensorimotor exercises	Injury recovery and reinjury prevention
Tejwani and Varadharajulu. **2024** **Physiotherapy** *Efficacy of cryotherapy and phonophoresis along with conventional exercises in tennis elbow patients.* **India**	Quasi-experimental study	To evaluate the effect of a combination of phonophoresis and cryotherapy on lateral epicondylitis	30 individuals aged 30–60 with lateral epicondylitis	Physical activity: light to moderate - Stretching - Strength exercises	treatment protocol (cryotherapy, phonophoresis and cryotherapy) Cryotherapy applied directly to the area (lateral epicondyle) for 10 min. Rest for 10 min. Application of continuous ultrasound with an intensity of 1.5 W/cm^2 and a frequency of 1 MHz with diclofenac mixed with ultrasound gel as a means of coupling the ultrasound gel for 8 min (small circular movements over the part to be treated, continuous and overlapping). After the administration of phonophoresis, cryotherapy was repeated again for 10 min. The participants then underwent hand strengthening and	Injury recovery

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Author(s) Year Discipline Study/Title Country	Study Type	Objective	Population and Sample	Type of Physical Activity	Nursing Care Domain	Impact of Action (Prevention and/or Recovery)
					stretching exercises four times a week for 6 weeks.	
Montalvo et al. **2014** **Sports Medicine** *Effect of kinesiology taping on pain in individuals with musculoskeletal injuries: systematic review and meta-analysis* **USA**	Systematic Literature Review and Meta-Analysis	To evaluate the effectiveness of kinesiology taping on pain reduction in individuals with musculoskeletal injuries	Individuals with musculoskeletal injuries included across 13 randomized and quasi-randomized trials	Light to moderate physical activity intensity. Physical activity not directly specified; adjunctive use with therapeutic exercise	Pain modulation: supportive care in musculoskeletal rehabilitation. Kinesiology taping is used as an adjunct to rehabilitation interventions. Symptom-oriented musculoskeletal pain management (adjunctive supportive intervention alongside therapeutic exercise)	Injury recovery
Li et al. **2024** **Sports medicine** *The efficacy of kinesio tape in patients with lateral elbow tendinopathy: A systematic review and meta-analysis of prospective randomized controlled trials* **China**	Systematic Review and Meta-Analysis of randomized controlled trials	To determine the efficacy of Kinesio tape in improving clinical outcomes (pain and function) in patients with lateral elbow tendinopathy by synthesizing evidence from randomized controlled trials.	Patients diagnosed with lateral elbow tendinopathy (also known as tennis elbow); combined n = 562 participants across included randomized controlled trials	Kinesio tape application as an adjunctive modality in rehabilitation — not exercise per se, but a therapeutic support intervention used during physical activity/functional tasks in musculoskeletal rehabilitation contexts (participants performed functional movements, therapeutic exercises, and daily or work-related upper-limb activities during rehabilitation.).	Therapeutic interventions for pain and functional improvement. Activity support/comfort management Clinical outcome evaluation within rehabilitation care contexts. (In broader allied healthcare settings, involved in coordinating or applying similar modalities when protocol driven.)	Injury recovery
Chen **2014** **Rehabilitation** *Bioelectrical stimulation therapy for muscle injuries in aerobics athletes* **China**	Experimental intervention study with a single-blind design	To evaluate the therapeutic effect of bioelectrical stimulation therapy on functional recovery, pain reduction, flexibility, electromyographic outcomes, and recurrence rates in aerobics athletes with muscle injuries.	100 aerobics athletes with clinically identified muscle injuries.	Medium-to-high intensity physical activity; typical of competitive or recreational aerobics.	Pain management and recovery facilitation. Monitoring and therapeutic support Functional recovery and activity adaptation. Multidisciplinary rehabilitation coordination. Best applied within clinical rehabilitation teams, including nursing roles where relevant.	Injury recovery and reinjury prevention
Ndayisenga et al. **2024** **Physical Education** *Assessing the effectiveness of a developed therapeutic massage and exercise model for the rehabilitation of back musculoskeletal disorders* **Indonesia**	Quasi-experimental	To evaluate the effectiveness of an integrative therapeutic model combining therapeutic massage and structured exercise for rehabilitation of back musculoskeletal disorders.	24 participants with diagnosed back musculoskeletal injuries (5 male, 19 female; aged 28–62) recruited via purposive sampling.	Moderate physical activity rehabilitation context: Structured exercise designed to improve flexibility, strength, and ROM, performed alongside therapeutic massage as part of an integrated rehabilitation model.	Relevant to multiple rehabilitative nursing domains, including: pain management and relief, functional mobility and ROM optimization, therapeutic exercise guidance and support, multidisciplinary rehabilitation integration.	Injury recovery
Needle et al. **2024** **Sports Rehabilitation** *Neural-Targeted Rehabilitation Strategies to Address Neuroplasticity After Joint Injury* **USA**	Conceptual article/narrative proposal	To propose and describe neural-targeted rehabilitation strategies that address maladaptive neuroplasticity in patients recovering from musculoskeletal injuries, integrating sensorimotor therapy, motor learning, neuromodulation and affective/cognitive interventions to improve recovery and reduce reinjury risk.	Not applicable — conceptual work synthesizing evidence and proposing rehabilitation frameworks rather than reporting primary patient data. The focus is on individuals with musculoskeletal joint injuries generally (e.g., ligament sprains, instability).	Not linked to a specific sport or intensity level	Support of neuromuscular recovery and sensorimotor integration, facilitation of return to activity, integration of cognitive/affective strategies to improve engagement and movement outcomes. Collaboration in multidisciplinary care for musculoskeletal injuries.	Injury recovery and reinjury prevention

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Author(s) Year Discipline Study/Title Country	Study Type	Objective	Population and Sample	Type of Physical Activity	Nursing Care Domain	Impact of Action (Prevention and/or Recovery)
Vittala et al. **2024** **Physical Therapy** *Physical therapy management for muscle tightness in a surfing athlete: a case report study* **Indonesia**	Case report	To describe physical therapy management and outcomes for muscle tightness in a surfing athlete with a history of ACL reconstruction and meniscectomy.	One 51-year-old male surfing athlete from New Zealand with muscle tightness and prior ACL reconstruction plus meniscectomy.	Moderate-to-high physical activity	Therapeutic exercise (ROM, strength training). Electrotherapy modalities (TENS, ultrasound). Manual therapy (massage, joint mobilization). Pain management support.	Injury recovery and reinjury prevention
Rossi **2024** **Rehabilitation** *Heat therapy for different knee diseases: expert opinion* **Italy**	Expert opinion	To review and provide expert insight into the role of heat therapy for various knee conditions including arthrosis, arthritis, traumatic injuries, and muscle/tendon pathologies focusing on mechanisms, clinical effects, and therapeutic implications in musculoskeletal rehabilitation.	Not applicable (no primary sample). The article synthesizes studies involving individuals with knee musculoskeletal conditions.	Moderate physical activity modalities supporting recovery and pain relief during activity and functional tasks.	Pain relief support, facilitation of mobility and functional activity, integration with exercise and physical therapy, patient education about modality uses and contraindications	Injury recovery
Liu **024** **Sports Psychology** *The effectiveness and applicability of mindfulness intervention in psychological adaptation after sports injury: a systematic review* **Malaysia**	Systematic review	To explore the effects and applicability of mindfulness interventions (MI) on psychological adaptation outcomes (anxiety, depression, acceptance, mindfulness level, pain tolerance, psychological well-being) in athletes after injury.	Review of studies involving injured athletes (musculoskeletal sports injuries); includes mixed designs across multiple primary studies, not a single sample.	Focus on athletes engaged in sport and physical activity settings, where psychological adaptation to injury and recovery is central. Not linked to a specific intensity category but applies broadly to sport-related injury rehabilitation.	Psychological support and adaptation. Pain perception and coping. Mental well-being and functional recovery engagement. These align with rehabilitative care support roles in multidisciplinary rehabilitation.	Injury recovery
Shin et al. **2020** **Medicine/ Rehabilitation** *Add-on effect of kinesiotape in patients with acute lateral ankle sprain: A randomized controlled trial* **South Korea**	Randomized controlled trial	To evaluate the add-on effect of kinesiotape (KT) when combined with acupuncture compared with acupuncture alone in adults with acute lateral ankle sprain (ALAS) for outcomes including pain, edema, function, activities of daily living (ADLs), quality of life, and recurrence.	Adults with grade I or II acute lateral ankle sprains. Participants were randomized into two groups (acupuncture alone vs acupuncture + KT); approximately 60–83 total participants across centers (30 per group).	Moderate to high physical activity: sports and active movement contexts	Adjunctive therapeutic modalities (kinesiotape). Support of pain management and joint function Promotion of activity participation and activities of daily living post injury.	Injury recovery
Melese et al. **2020** **Rehabilitation Sciences** *Effectiveness of Kinesio Taping on the Management of Knee Osteoarthritis: A Systematic Review of Randomized Controlled Trials* **Ethiopia**	Systematic review of randomized controlled trials	To synthesize evidence on the effectiveness of kinesio taping in reducing pain and improving joint function in patients with knee osteoarthritis.	Patients with knee osteoarthritis; 18 RCTs involving 876 participants were included.	Daily activity and functional mobility – light to moderate intensity.	Relevant to rehabilitative care domains, including pain management, functional activity facilitation, and support of mobility; relevant to multidisciplinary rehabilitation including nursing roles.	Injury recovery and injury prevention
Pastora-Bernal et al. **2018** **Physiotherapy** *Telerehabilitation after arthroscopic subacromial decompression is effective and not inferior to standard practice: Preliminary results* **Spain**	Prospective, controlled trial	To evaluate the feasibility and effectiveness of a telerehabilitation program after arthroscopic subacromial decompression surgery and to compare it to standard face-to-face physical therapy.	Adults who underwent arthroscopic subacromial decompression surgery for shoulder pain attributed to subacromial impingement. Telerehabilitation group: 9 patients Standard physiotherapy group: 9 patients	Moderate physical activity related to functional practice/ movements	A structured program delivered remotely — including range of motion exercises and strengthening of the rotator cuff and scapular stabilizers.	Injury recovery

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Author(s) Year Discipline Study/Title Country	Study Type	Objective	Population and Sample	Type of Physical Activity	Nursing Care Domain	Impact of Action (Prevention and/or Recovery)
Kivlan et al. **2015** **Rehabilitation** *The effect of Astym® Therapy on muscle strength: a blinded, randomized, clinically controlled trial Rehabilitation, physical therapy and occupational health* **USA**	Blinded, randomized controlled trial	To determine whether a single session of Astym® therapy applied to the lower extremity produces an immediate increase in maximal muscle force output, as measured by a unilateral isometric squat test, in individuals with lower extremity musculoskeletal injury.	Population: adults aged 18–65 years presenting with musculoskeletal injury and associated lower extremity muscular weakness. Sample size: 45 (15 per group).	Moderate functional activity	Astym® Therapy Group: manual therapy technique applied using specialized instruments designed to stimulate soft tissue and neuromuscular response. Applied to muscles of the anterior and lateral compartments of the leg, gastrocnemius/soleus, quadriceps, hamstrings, gluteus maximus, and gluteus medius on the involved side. Mechanism: Instrument-assisted stimulation intended to facilitate soft tissue healing, neuromuscular facilitation, and pain modulation. Functional support (enhance mobility and activity tolerance), pain modulation (manual therapy).	Injury recovery
Camargo et al. **2014** **Physical Therapy** *Eccentric training as a new approach for rotator cufftendinopathy: Review and perspectives* **Brazil**	Narrative review	To review and discuss eccentric training as a therapeutic approach for rotator cuff tendinopathy	Individuals with rotator cuff tendinopathy; no primary sample	Moderate–intense therapeutic exercise; repetitive functional activity, recreational and sport-related activity	Core Intervention (eccentric training): controlled lengthening contractions of rotator cuff muscles, performed under load, progressive intensity. Multidisciplinary care: therapeutic exercise support, pain management through non-pharmacological means, patient education and self-management, adherence monitoring and functional progression.	Injury recovery
Cavalcante & Almeida **2024** **Sports Science** *Intervenções fisioterapêuticas no tratamento de lesões por esforço repetitivo em atletas.* **Brazil**	Conference Communication	To evaluate techniques applied to repetitive strain injuries.	Amateur and competitive athletes exposed to repetitive strain; no specific sample.	Multisport: moderate–intense physical activity	Stretching. Muscle strengthening. Eccentric exercises. Extracorporeal Shockwave Therapy. Adjusting volume, intensity, and load progression is essential for the recovery of athletes with repetitive strain injury. Functional re-education (functional improvement, pain reduction).	Prevention (reduction of recurrence); Injury recovery.
Rios et al. **2024** **Physiotherapy/ Rehabilitation** *Rehabilitation Protocols in Patients with Musculoskeletal Injuries: An Integrative Review* **Brazil**	Integrative Review	To identify and analyze the most effective rehabilitation protocols for patients with musculoskeletal injuries, highlighting interventions that produce better functional outcomes.	Adults with musculoskeletal injuries; individual study samples not specified	Multisport: moderate–intense physical activity	Combination of strengthening exercises, stretching, joint mobilization, supervised manual therapy, electrotherapy, shockwave therapy; individualized rehabilitation protocols adjusted in intensity, frequency, and type of exercise according to severity of the injury; pain tolerance; stage of tissue healing; functional goals of the patient/athlete.	Injury recovery and recurrence.

predominated in later rehabilitation phases or athletic/military populations, while light-to-moderate intensity was applied in older adults, chronic conditions, or early rehabilitation (Gribble et al., 2023; Melese et al., 2020; Petersen et al., 2013; Rogers et al., 2013). High-intensity activity was reserved for elite athletes, with careful progression to ensure tissue healing and safe return to sport (Hatta et al., 2018; Rosado-Velazquez et al., 2020; Tavakol et al., 2019; Young et al., 2023).

4.2.2. Progression and management of activity

A key theme was **progressive and individualized management** rather than fixed intensity prescriptions. Interventions described graduated loading, adjustment of exercise volume, and alignment with tissue healing phases (Camargo et al., 2014; Rios et al., 2024; Steere et al., 2021). Health education and behavioral strategies were often integrated, addressing pain management, fear of movement, sleep, nutrition, and adherence (Alcock et al., 2024; Chennaoui et al., 2021; Colgan et al., 2023; Liu and Noh, 2024; Wideman and Sullivan, 2012).

Progressive, supervised, and context-specific physical activity was central for safe recovery and reinjury prevention, highlighting the critical role of nursing in monitoring, guidance, and patient education.

4.2.3. Impact of interventions on people with musculoskeletal injuries

According to the studies included, rehabilitative interventions were consistently associated with positive clinical, functional, and behavioral outcomes in individuals with musculoskeletal injuries. Reported benefits most frequently included pain reduction, improvements in joint range of motion, enhanced neuromuscular control and stability, and gains in functional performance across daily activities, occupational tasks, and sport-specific demands (Booth-Kewley et al., 2009; Catapano et al., 2022; Colgan et al., 2023; Coppack et al., 2016; Gribble et al., 2023; Rosado-Velazquez et al., 2020; Young et al., 2023). These outcomes were predominantly associated with integrated and progressive rehabilitation programs, combining therapeutic exercise, balance and proprioceptive training, flexibility, and structured health education. Such approaches are aligned with contemporary orthopedic and trauma nursing principles, which emphasize functional recovery, safe reintegration into activity, and long-term self-management rather than isolated symptom control. Across the evidence base, two overarching intervention objectives were consistently identified:

- Recovery from musculoskeletal injury: a substantial proportion of the evidence focused on recovery from musculoskeletal injury, with interventions aimed at restoring physical function, reducing pain, and enabling return to activity. Across athletic, military, older adult and general populations, recovery-oriented programs commonly integrated strength training, balance and proprioceptive exercises, flexibility and mobility work, and manual or physical modalities (Booth-Kewley et al., 2009; Camargo et al., 2014; Catapano et al., 2022; Colgan et al., 2023; Coppack et al., 2016; Gribble et al., 2023; Hatta et al., 2018; Rogers et al., 2013; Rosado-Velazquez et al., 2020; Steere et al., 2021; Tavakol et al., 2019; Tejwani and Varadharajulu, 2024; Vuletić and Bøe, 2024; Young et al., 2023).

In high-demand populations such as athletes and military personnel, recovery interventions extended beyond symptom resolution to include performance-related outcomes, emphasizing readiness for return to sport or duty and resilience to physical load (Cavalcante and Almeida, 2024; Chen, 2024; Coppack et al., 2016; Liu and Noh, 2024; McGuine and Keene, 2006; Rios et al., 2024; Tavakol et al., 2019; Vittala et al., 2024; Yalfani et al., 2024; Young et al., 2023). In contrast, studies involving older adults emphasized functional independence, balance, and fall risk reduction, with adaptations in exercise intensity and progression (Catapano et al., 2022; Gribble et al., 2023; Rogers et al., 2013; Vuletić and Bøe, 2024). Combined protocols including strength training, balance, manual therapy and postural re-education have been shown to be effective in restoring physical function (Dedes et al., 2019; Kivlan et al., 2015; Li et al., 2024; Melese et al., 2020; Montalvo et al., 2014; Ndayisenga et al., 2024; Needle and Howard, 2024; Pastora-Bernal et al., 2018; Rossi, 2024; Shin et al., 2020; Wideman and Sullivan, 2012).

- Prevention of recurrence: prevention-oriented strategies were a prominent component particularly in studies addressing chronic or recurrent musculoskeletal conditions. Preventive approaches included proprioceptive and neuromotor training, education on safe physical activity progression, use of assistive or orthotic devices, and behavioral interventions aimed at improving adherence and self-efficacy (Bellows and Wong, 2018; Catapano et al., 2022; Petersen et al., 2013; Vuletić and Bøe, 2024; Yalfani et al., 2024; Young et al., 2023).

Several studies highlighted that education-based interventions, when integrated with physical rehabilitation, contributed to improved load management and reduced recurrence risk, particularly in athletic and occupational contexts (Alcock et al., 2024; Booth-Kewley et al., 2009; Colgan et al., 2023; Coppack et al., 2016). These findings reinforce the importance of rehabilitative nursing in supporting sustained engagement with safe physical activity beyond the supervised intervention period.

4.2.4. Nursing-relevant intervention domains

Analysis of the included studies, multiple intervention domains directly aligned with nursing practice, spanning physical, educational, psychosocial, and supportive care components. Nursing-relevant contributions were evident in both holistic, person-centered rehabilitation models and focused, modality-driven protocols, frequently delivered within multidisciplinary care frameworks (Alcock et al., 2024; Bellows and Wong, 2018; Booth-Kewley et al., 2009; Camargo et al., 2014; Catapano et al., 2022; Cavalcante and Almeida, 2024; Chennaoui et al., 2021; Colgan et al., 2023; Coppack et al., 2016; Dedes et al., 2019; Gribble et al., 2023; Hatta et al., 2018; Kivlan et al., 2015; Li et al., 2024; Liu and Noh, 2024; McGuine and Keene, 2006; Melese et al., 2020; Montalvo et al., 2014; Ndayisenga et al., 2024; Needle and Howard, 2024; Pastora-Bernal et al., 2018; Petersen et al., 2013; Rios et al., 2024; Rogers et al., 2013; Rosado-Velazquez et al., 2020; Rossi, 2024; Shin et al., 2020; Steere et al., 2021; Tavakol et al., 2019; Tejwani and Varadharajulu, 2024; Vittala et al., 2024; Vuletić and Bøe, 2024; Wideman and Sullivan, 2012; Yalfani et al., 2024; Young et al., 2023).

A central domain across the literature was the supervision and progression of therapeutic exercise, encompassing strength, balance, proprioceptive, flexibility, and aerobic training. This domain was present in studies involving youth, adult, and older athletes, military personnel, occupational populations, and individuals with chronic or acute musculoskeletal conditions (Catapano et al., 2022; Coppack et al., 2016; Gribble et al., 2023; Hatta et al., 2018; McGuine and Keene, 2006; Ndayisenga et al., 2024; Petersen et al., 2013; Vittala et al., 2024; Vuletić and Bøe, 2024; Yalfani et al., 2024). Patient education represented another core nursing domain, addressing pain self-management, behavioral adaptation, sleep and rest, adherence to rehabilitation, and safe progression of physical activity. Educational interventions were particularly emphasized in studies focusing on psychosocial determinants of recovery, chronic pain, occupational injury, and long-term self-management (Alcock et al., 2024; Booth-Kewley et al., 2009; Chennaoui et al., 2021; Colgan et al., 2023; Liu and Noh, 2024; Rios et al., 2024; Wideman and Sullivan, 2012).

The integration of complementary and adjunctive modalities including cryotherapy, hydrotherapy, electrotherapy, shockwave therapy, ultrasound, kinesiology taping, heat therapy, and instrument-assisted soft tissue techniques, was widely reported as part of multimodal rehabilitation programs (Dedes et al., 2019; Kivlan et al., 2015; Li et al., 2024; Melese et al., 2020; Montalvo et al., 2014; Rossi, 2024; Shin et al., 2020; Steere et al., 2021; Tavakol et al., 2019; Tejwani and

Varadharajulu, 2024). These modalities were consistently described as supportive interventions, facilitating pain modulation, tissue recovery, and tolerance to therapeutic exercise.

Monitoring of individual response and tolerance to physical activity, including symptom evolution, fatigue, pain, and functional capacity, was another recurrent domain, supporting individualized progression and safety across rehabilitation phases (Catapano et al., 2022; Coppack et al., 2016; Pastora-Bernal et al., 2018; Rios et al., 2024; Rosado-Velazquez et al., 2020; Vuletić and Bøe, 2024).

Consistent with the data extracted in Table 1, most studies adopted multimodal and progressive intervention strategies, reflecting a prevailing trend in contemporary musculoskeletal rehabilitation toward the integration of multiple therapeutic components rather than isolated techniques.

4.2.5. Focused versus holistic rehabilitation models

Most studies favored holistic rehabilitation approaches, integrating physical, psychological, educational and behavioral components. These models were particularly evident in studies addressing complex recovery trajectories, recurrent injuries, chronic pain, or high-performance contexts, where physical recovery alone was insufficient to ensure sustained return to activity (Booth-Kewley et al., 2009; Colgan et al., 2023; Coppack et al., 2016; Liu and Noh, 2024; Needle and Howard, 2024; Rios et al., 2024; Wideman and Sullivan, 2012).

Holistic approaches frequently incorporated psychosocial support, cognitive strategies and education alongside therapeutic exercise and physical modalities, highlighting the interaction between physical and psychological determinants of recovery (Booth-Kewley et al., 2009; Chennaoui et al., 2021; Colgan et al., 2023; Liu and Noh, 2024; Wideman and Sullivan, 2012).

In contrast, several studies reported focused interventions targeting specific domains or modalities. These included electrotherapy-based protocols, shockwave therapy, ultrasound, phonophoresis, kinesiology taping, heat therapy, and sleep-focused education (Chennaoui et al., 202; Dedes et al., 2019; Melese et al., 2020; Rossi, 2024; Shin et al., 2020; Tavakol et al., 2019; Tejwani and Varadharajulu, 2024). Although narrower in scope, these interventions were described as contributing meaningfully to recovery, pain modulation, or relapse prevention when appropriately indicated and integrated within broader care pathways.

4.2.6. Multidisciplinary and interprofessional context

Most rehabilitation programs described in the included studies were embedded within multidisciplinary and interprofessional frameworks, commonly involving orthopedic and trauma nursing, physiotherapy, sports medicine, rehabilitation medicine, psychology, nutrition, exercise science, and, in some cases, occupational health (Booth-Kewley et al., 2009; Catapano et al., 2022; Colgan et al., 2023; Coppack et al., 2016; Needle and Howard, 2024; Petersen et al., 2013; Rios et al., 2024).

The benefits of multidisciplinary collaboration were particularly evident in studies involving military personnel, athletes, and individuals with complex or recurrent musculoskeletal conditions. Coppack et al. (2016) demonstrated that an intensive multidisciplinary residential program for military personnel resulted in superior functional outcomes compared with conventional outpatient rehabilitation. Similarly, Colgan et al. (2023) and Young et al. (2023) highlighted how integrating physical training with cognitive, educational, and psychosocial strategies supported confidence, adherence, and safe return to high-demand activities.

Psychosocial and behavioral dimensions were consistently recognized as influential factors in recovery trajectories, particularly in contexts of chronic pain, prolonged disability, or high-performance demands (Booth-Kewley et al., 2009; Liu and Noh, 2024; Wideman and Sullivan, 2012). The involvement of interdisciplinary teams enabled a person-centered and context-sensitive approach, extending rehabilitation goals beyond symptom resolution toward functional autonomy, health literacy, and long-term engagement in safe physical activity (Catapano et al., 2022; Vuletić and Bøe, 2024).

Overall, the evidence indicates that effective rehabilitation of musculoskeletal injuries depends on coordinated, progressive, and interdisciplinary care models, in which nursing-relevant domains play a central role in supporting recovery, prevention of recurrence, and sustainable functional outcomes.

5. Discussion

This scoping review extends existing musculoskeletal rehabilitation literature by explicitly foregrounding domains traditionally aligned with rehabilitation nursing. While previous reviews have predominantly emphasized biomechanical outcomes and performance metrics within physiotherapy or sports medicine frameworks, the present synthesis highlights rehabilitation as a person-centered, adaptive, and longitudinal process.

The heterogeneity observed in intervention duration and intensity reflects deliberate personalization based on individual clinical profiles, psychosocial readiness, and contextual demands. This reinforces the importance of ongoing assessment, monitoring, and progression of physical activity throughout the rehabilitation trajectory. Psychological and educational dimensions, often underrepresented in discipline-specific reviews, emerged as integral to recovery, adherence, and prevention of recurrence, particularly in chronic and high-demand populations.

The integration of technological and adjunctive modalities further underscores the need for coordinated oversight to ensure safety, appropriate use, and alignment with active rehabilitation goals. Lifestyle and nutritional considerations, although peripheral in many traditional musculoskeletal reviews, were consistently linked to recovery optimization and align with holistic models of care.

5.1. Summary of evidence

This scoping review systematically mapped the available scientific evidence describing nursing relevant interventions for individuals with musculoskeletal injuries related to physical activity. A total of 36 studies were identified across heterogeneous populations, injury types, and practice contexts, including athletes, military personnel, older adults, and individuals with acute and chronic musculoskeletal conditions. The breadth and variability of the evidence confirm the appropriateness of a scoping review design to clarify key concepts, characterize intervention domains, and identify gaps in literature.

Across the included studies, nursing interventions were predominantly embedded within multimodal and progressive rehabilitation programs rather than described as isolated or discipline-specific actions. Therapeutic exercise emerged as the central component of care, typically combined with education, psychosocial support, symptom monitoring, and adjunctive modalities. Interventions were consistently tailored to individual capacity, stage of recovery, and contextual demands, with progression of physical activity prioritized over fixed or standardized intensity prescriptions. These patterns directly address the review question by demonstrating that nursing interventions in this context are characterized by coordinated, person-centered rehabilitation processes rather than discrete technical procedures.

The synthesis highlights that nursing contributions extend beyond the physical domain to include supervision of activity progression, pain and symptom management, promotion of health literacy, behavioral adaptation, and continuity of care across rehabilitation phases. Although few studies explicitly identified nurse-led interventions, nursing practice was implicitly central to the implementation, monitoring, and integration of rehabilitation strategies within multidisciplinary teams. These findings underscore both the relevance of nursing practice in musculoskeletal rehabilitation and a significant gap in the explicit reporting of nursing-specific outcomes and leadership.

For healthcare providers, particularly nurses, the evidence supports

the value of individualized, progressive, holistic rehabilitation approaches that integrate physical activity with education and psychosocial care. For policymakers and healthcare managers, the findings emphasize the need to formally recognize and support rehabilitation nursing roles within interdisciplinary musculoskeletal care pathways.

For patients and consumers, the evidence reinforces the importance of education, self-management support, and supervised progression of physical activity in promoting safe recovery, preventing recurrence, and sustaining long-term functional outcomes.

Overall, this scoping review clarifies the scope and characteristics of nursing-relevant interventions for musculoskeletal injuries associated with physical activity while identifying critical gaps in nurse-led research. Addressing these gaps through future studies may strengthen evidence-informed nursing practice and enhance the visibility of nursing contributions as an integrative and coordinating discipline, central to the delivery of safe, individualized, and sustainable rehabilitation pathways.

In this scoping review, we mapped and synthesized the available evidence describing nursing interventions for individuals with musculoskeletal injuries related to physical activity. A total of 36 studies were identified across diverse populations, injury types, and practice contexts, including athletes, military personnel, older adults, and individuals with acute and chronic musculoskeletal conditions. The evidence demonstrates that nursing-relevant interventions are predominantly embedded within multimodal and progressive rehabilitation programs, integrating therapeutic exercise, activity monitoring, health education, psychosocial support, and coordination within multidisciplinary teams.

The findings directly address the guiding research question *"What nursing interventions are described in the scientific literature for individuals with musculoskeletal injuries related to physical activity?"* by demonstrating that nursing interventions extend beyond task-oriented care and encompass supervision of physical activity progression, pain and symptom management, patient education, behavioral and psychosocial support, and continuity of care across rehabilitation phases. These interventions are consistently aligned with recovery from injury and prevention of recurrence, although they are often described implicitly within interdisciplinary rehabilitation frameworks rather than as nurse-led models.

Given the diversity of injury mechanisms, heterogeneity of populations and settings, and the wide range of interventions reported, a scoping review was the most appropriate methodological approach to systematically map existing evidence, clarify key concepts, and identify knowledge gaps. Notably, the review highlights a paucity of studies explicitly authored by nurses or clearly attributing outcomes to nursing-led interventions, despite the central role of nursing practice within rehabilitation pathways.

6. Limitations

Several limitations should be considered when interpreting the findings of this scoping review, both in relation to the review process itself and to the nature and extent of the available evidence.

First, although a comprehensive and systematic search strategy was employed across multiple databases, it is possible that relevant studies were not identified, particularly those published in non-indexed journals or outside the selected languages. While the inclusion of grey literature aimed to mitigate publication bias and enhance the breadth of evidence, grey sources were limited in number and may vary in methodological rigor. Consequently, some nursing interventions implemented in practice may remain underrepresented in the published literature.

Second, consistent with the objectives of a scoping review, no meta-analysis was conducted, and the methodological quality of the included studies was not used to weight findings. The heterogeneity of study designs, populations, and outcome measures limits direct comparison across studies and precludes causal inferences regarding intervention effectiveness. The findings therefore reflect the range and nature of reported nursing interventions, rather than their comparative efficacy.

Third, the review captured a broad spectrum of populations, including athletes, military personnel, older adults, and occupational groups. While this diversity strengthens the generalizability of the mapped intervention domains, it also introduces variability in injury types, functional demands, and rehabilitation contexts. As a result, some intervention components may be highly context-specific, and their applicability to other populations should be interpreted cautiously.

Regarding protocol adherence, a notable deviation from the initial review plan involved the update and expansion of the literature search, which resulted in the inclusion of additional studies beyond those initially screened. This decision was driven by the emergence of newly published evidence and the recognition that earlier search iterations did not fully capture the evolving scope of nursing-relevant rehabilitation interventions. Although this update increased the comprehensiveness and currency of the review, it also necessitated reclassification of study characteristics and expansion of the synthesis. This deviation may have influenced the distribution of intervention domains and study designs identified; however, it ultimately strengthens the validity and relevance of the findings by ensuring alignment with current practice.

Another limitation relates to the variable reporting of nursing-specific roles within the included studies. In many articles, interventions were delivered within multidisciplinary teams without clearly delineating professional responsibilities. This limited the ability to attribute specific outcomes exclusively to nursing interventions and may have led to conservative interpretation of nursing contributions. Nevertheless, this reflects real-world rehabilitation practice, where nursing roles are often integrative and relational rather than isolated or protocol-driven.

Finally, although the review aimed to comprehensively map nursing interventions across the rehabilitation continuum, the evidence base remains unevenly distributed, with a greater emphasis on recovery-oriented interventions compared with long-term follow-up, community reintegration, or policy-level outcomes. This gap highlights important areas for future research, particularly regarding the sustained impact of nursing-led interventions on recurrence prevention, self-management, and health system efficiency.

Taken together, these limitations do not undermine the core contributions of the review but rather define the boundaries of interpretation. The scoping review provides a structured and transparent overview of nursing interventions for musculoskeletal injuries during physical activity, while also identifying areas where the literature remains fragmented or underdeveloped. Recognizing these limitations strengthens the credibility of the findings and supports informed application in practice, education, and policy.

7. Conclusions

In this scoping review, we mapped evidence from 36 studies addressing rehabilitation interventions for musculoskeletal injuries associated with physical activity, with a specific focus on nursing-relevant domains of care. The findings demonstrate that musculoskeletal rehabilitation is characterized by substantial heterogeneity in intervention duration, intensity, and modality, reflecting deliberate personalization based on population characteristics, injury profiles, psychosocial readiness, and physical activity demands rather than inconsistency in care.

Across clinical, occupational, athletic, and community settings, effective rehabilitation consistently relied on individualized and progressive physical activity, integration of psychosocial and educational strategies, and multimodal, interdisciplinary approaches. Educational interventions promoting health and physical literacy, self-management, and behavioral adaptation, together with psychosocial strategies addressing fear of movement and maladaptive beliefs, emerged as key contributors to adherence, functional recovery, and sustained

engagement in physical activity. Technological and adjunctive therapeutic modalities showed benefit when appropriately supervised and integrated within comprehensive rehabilitation plans, while lifestyle and nutritional factors supported tissue healing and preservation of functional capacity.

For healthcare providers, particularly rehabilitation nurses, these findings support an expanded role in musculoskeletal injury management, encompassing individualized exercise supervision, psychosocial assessment, patient education, symptom management, and coordination of interdisciplinary care. For policymakers and healthcare system planners, the evidence underscores the need to formally recognize rehabilitation nursing as a core component of musculoskeletal care pathways across healthcare, occupational, and sporting systems. For patients and physically active individuals, the findings reinforce the value of person-centered, supervised, and progressive rehabilitation approaches that promote safety, autonomy, and long-term self-management.

7.1. Contribution to knowledge and future directions

By mapping nursing relevant intervention domains across a diverse body of literature, this scoping review extends existing sport medicine and physiotherapy focused reviews and reframes musculoskeletal rehabilitation as a complex, person-centered, and longitudinal process. Nursing interventions emerge as central to functional recovery, prevention of recurrence, and sustainable return to physical activity. Future research should prioritize high-quality studies evaluating nurse-led and nursing-sensitive outcomes and explore implementation strategies that strengthen the integration of rehabilitation nursing across clinical, community, and athletic contexts.

CRediT authorship contribution statement

J. Pinheiro: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **A. Costa:** Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Conceptualization. **P. Pedrosa:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **C. Marques-Vieira:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

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Declaration of competing interest

The authors certify that they haven't affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

Appendix A. Supplementary data

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