Más allá de la reparación: repensando la recuperación funcional en las lesiones musculoesqueléticas

Beyond the Repair: Rethinking Functional Recovery in Musculoskeletal Injury

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RESUMEN

Las lesiones musculoesqueléticas representan una de las principales causas de discapacidad a nivel mundial; sin embargo, la reparación estructural exitosa no siempre se traduce en una recuperación funcional completa. Este estudio analiza la evidencia reciente (2020 en adelante) sobre la recuperación funcional tras lesiones musculoesqueléticas, enfatizando la transición de modelos centrados en la estructura hacia enfoques orientados a la función. Se realizó una revisión narrativa estructurada con componentes sistemáticos basada en PRISMA, utilizando estudios de alto impacto de bases como PubMed, Scopus y Web of Science. Los resultados muestran una discrepancia persistente entre la curación anatómica y los resultados funcionales, con déficits frecuentes en fuerza, control neuromuscular, resistencia y preparación psicológica, incluso después de tratamientos exitosos. Las estrategias de rehabilitación basadas en entrenamiento neuromuscular, progresión de cargas y criterios funcionales demostraron mejores resultados, mientras que los protocolos basados únicamente en tiempo mostraron menor utilidad. Asimismo, factores psicológicos como el miedo a la reinjuria y la baja confianza influyen significativamente en la recuperación y el retorno a la actividad. Se observó que regresar a la actividad no implica recuperación completa, ya que muchos pacientes lo hacen con limitaciones.

PALABRAS CLAVE

lesión musculoesquelética, recuperación funcional, rehabilitación, control neuromuscular, manejo de carga, retorno al deporte, resultados ortopédicos, modelo biopsicosocial, fisioterapia, traumatología

ABSTRACT

Musculoskeletal injuries remain a leading cause of disability worldwide, yet successful structural repair does not consistently translate into full functional recovery. This review analyzes current evidence (2020 onward) on functional recovery after musculoskeletal injury, emphasizing the transition from structure-centered to function-oriented models of care. A structured narrative review with systematic components was conducted following PRISMA-based principles, including high-impact studies from databases such as PubMed, Scopus, and Web of Science. The findings demonstrate a persistent discrepancy between anatomical healing and functional outcomes, with frequent deficits in strength, neuromuscular control, endurance, and psychological readiness despite successful treatment. Rehabilitation strategies centered on neuromuscular training, progressive load management, and criteria-based progression were consistently associated with improved functional outcomes. In contrast, time-based protocols showed limited reliability for determining readiness to return to activity. Additionally, psychological factors such as fear of reinjury and reduced confidence were identified as key determinants influencing recovery trajectories and return-to-activity decisions. The analysis also revealed that return to activity does not necessarily indicate full recovery, as many patients resume participation with limitations or at a reduced level.

KEYWORDS

musculoskeletal injury, functional recovery, rehabilitation, neuromuscular control, load management, return to sport, orthopedic outcomes, biopsychosocial model, physical therapy, trauma care

INTRODUCCIÓN

Musculoskeletal injuries represent one of the leading causes of disability worldwide, significantly impacting quality of life, work productivity, and long-term health outcomes. Traditionally, the management of these conditions in Traumatology has focused on structural repair—whether through surgical intervention or conservative management—prioritizing anatomical restoration as the primary endpoint. However, emerging evidence suggests that structural healing alone does not necessarily translate into optimal functional recovery, particularly in active populations and individuals requiring high levels of physical performance (Buckthorpe et al., 2021), (Dingenen & Gokeler, 2021), This discrepancy has led to a paradigm shift toward understanding recovery as a multidimensional process that integrates biomechanical, neuromuscular, and psychosocial factors.

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Recent literature highlights that functional recovery extends beyond tissue healing, encompassing neuromuscular control, proprioception, psychological readiness, and return-to-activity metrics (Hurley et al., 2021), (Khan et al., 2020). For instance, studies on anterior cruciate ligament (ACL) reconstruction demonstrate that even after successful surgical repair, deficits in quadriceps strength and neuromuscular coordination may persist, directly influencing reinjury risk and long-term joint health (Hurley et al., 2021), (Malliaras et al., 2020). Similarly, rehabilitation protocols following rotator cuff repair emphasize progressive loading and scapular control rather than solely focusing on tendon integrity (Cools et al., 2021), (Diercks et al., 2020). These findings underscore the need for a more comprehensive framework that prioritizes functional outcomes over purely structural benchmarks.

Globally, this issue has become increasingly relevant, particularly in regions such as Latinoamerican, where musculoskeletal disorders contribute significantly to the burden of disease and healthcare resource utilization. In these settings, disparities in access to rehabilitation services, variability in clinical protocols, and socioeconomic factors further complicate recovery trajectories. Moreover, the growing emphasis on return-to-work and return-to-sport outcomes necessitates standardized, evidence-based approaches that can be adapted across diverse healthcare systems.

Previous high-impact studies have explored different dimensions of this problem. The ESCAPE trial demonstrated that surgical interventions such as arthroscopy may not always provide superior outcomes compared to structured rehabilitation in degenerative knee conditions, reinforcing the importance of functional approaches (Beard et al., 2020). In parallel, systematic reviews on return-to-sport criteria emphasize the limitations of time-based protocols, advocating instead for objective functional testing and individualized progression (Belk et al., 2021), (Zadro et al., 2021). Furthermore, contemporary rehabilitation models incorporate load management strategies for tendinopathies and chronic musculoskeletal conditions, highlighting the role of progressive mechanical stimulation in tissue adaptation (Malliaras et al., 2020), (Silbernagel et al., 2020). These approaches align with broader frameworks in internal medicine and rehabilitation science that recognize the interplay between inflammation, biomechanics, and systemic health (Foster et al., 2020).

Another critical aspect addressed in recent research is the integration of psychosocial variables into recovery models. Fear of reinjury, patient expectations, and adherence to rehabilitation programs have been shown to significantly influence outcomes, sometimes even more than the severity of the initial injury (Lentz et al., 2020). This biopsychosocial perspective has gained traction as a cornerstone in modern musculoskeletal care, shifting clinical focus toward patient-centered strategies that account for individual variability and contextual factors.

Despite these advances, there remains a lack of consensus regarding the optimal integration of structural and functional paradigms in clinical practice. Variability in rehabilitation protocols, inconsistencies in outcome measures, and limited implementation of evidence-based guidelines continue to hinder progress. Additionally, while international guidelines such as the PRISMA 2020 statement have improved the quality of systematic reviews, the translation of evidence into clinical practice remains uneven (Page et al., 2021). This gap is particularly evident in low- and middle-income countries, where resource constraints and training disparities may limit the adoption of advanced rehabilitation strategies.

In this context, the present review aims to analyze the concept of functional recovery after musculoskeletal injury, emphasizing the transition from a structure-centered model to a function-oriented approach. The central research question guiding this work is: *How can functional recovery be optimized beyond structural repair in patients with musculoskeletal injuries?* From this, secondary questions emerge, including the role of neuromuscular rehabilitation, the impact of psychosocial factors, and the effectiveness of current return-to-activity criteria.

To address these questions, this study adopts a structured review methodology, integrating recent high-impact literature published from 2020 onward. The design aligns with established reporting standards and focuses on synthesizing evidence from clinical trials, systematic reviews, and consensus statements relevant to orthopedic and rehabilitation practice. The selection of studies prioritizes those indexed in major databases such as PubMed and those with validated methodological quality, ensuring the reliability of the conclusions drawn.

The methodological approach is directly aligned with the research objectives, as it allows for a comprehensive evaluation of current evidence while identifying gaps in knowledge and areas for future investigation. By combining

perspectives from different regions, including Mexico, Colombia, and Ecuador, this review also seeks to provide a broader understanding of how functional recovery strategies can be adapted to diverse healthcare contexts.

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DESARROLLO

Functional recovery after musculoskeletal injury should be understood as a broader clinical endpoint than structural healing alone. In contemporary traumatology and orthopedics, the traditional question—whether a bone, tendon, ligament, or joint has anatomically healed—has become insufficient to explain why many patients continue to show weakness, altered movement patterns, pain during specific tasks, reduced confidence, delayed return to sport, or incomplete return to work despite technically successful repair. The current literature consistently shows that structural restoration and functional restoration do not always progress in parallel. This distinction is central to the present review because it explains why patients with apparently favorable imaging or postoperative findings may still have important deficits in force production, motor control, endurance, coordination, and participation in daily or athletic activities. At a global level, musculoskeletal conditions remain the leading contributor to disability, affecting approximately 1.71 billion people, and they are also the largest contributor to the need for rehabilitation services worldwide. This epidemiologic burden justifies a shift from a purely tissue-centered model toward a function-centered model of care. (WHO, 2022)

A first major argument in favor of this shift is that successful recovery depends on the integration of biological healing with neuromuscular adaptation. This is especially evident after anterior cruciate ligament reconstruction, where return to activity is often discussed as if it were a predictable consequence of graft healing. In reality, more recent work shows that return to sport is influenced by multiple interacting domains, including strength symmetry, dynamic control, psychological readiness, reinjury risk, and sport-specific performance capacity. Contemporary reviews emphasize that the field has moved away from simple time-based clearance and toward criteria-based progression, because chronological milestones alone fail to capture the complexity of recovery. In this sense, functional recovery is not the passive result of waiting long enough after injury or surgery; it is an active process that must be built through staged rehabilitation, repeated reassessment, and individualized progression. (Gokeler et al., 2022; Turk et al., 2023)

The ACL literature provides one of the clearest demonstrations that anatomical success does not guarantee functional success. Even after reconstruction, deficits in quadriceps strength remain frequent and clinically relevant. These deficits are not minor findings: they are associated with poorer patient-reported outcomes and may compromise gait, landing mechanics, deceleration, and return-to-sport capacity. Van Wyngaarden and colleagues showed that quadriceps strength and kinesiophobia significantly predict long-term self-reported outcomes after ACL reconstruction, reinforcing the idea that recovery is shaped by both physical and psychological variables. Similarly, studies of neuromuscular performance show that altered landing strategies and biomechanical asymmetries can persist even in athletes who have already been cleared to return to sport. Therefore, the true endpoint of rehabilitation should not be the completion of surgery or the passage of months, but the restoration of efficient and confident movement under clinically relevant demands. (Van Wyngaarden et al., 2021; Smeets et al., 2021)

This has important implications for rehabilitation design. If force production, motor recruitment, and limb symmetry are not adequately restored, the patient may return with hidden deficits that are not obvious in a routine consultation but become evident during cutting, pivoting, landing, sprinting, or fatigue. More recent prognostic work on return to sport after ACL reconstruction confirms that readiness is multifactorial and cannot be captured by a single variable. In practice, this means that functional recovery must be evaluated through a combination of objective measures and contextual interpretation, rather than a single clinical milestone. For teaching purposes, this is an especially important point for medical students and trainees: the orthopedic result should be interpreted not only through imaging or surgical technique, but also through what the patient can safely and efficiently do afterward. (van Haren et al., 2025; Turk et al., 2023)

A second major line of evidence comes from tendon and overuse injury rehabilitation, where structural pathology often correlates imperfectly with symptoms and function. In tendinopathy, the literature has increasingly moved away from passive strategies and toward progressive loading models. The rationale is that the tendon responds to controlled

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mechanical stimulus, and clinical improvement depends less on "resting" the tissue indefinitely than on exposing it to the right kind of load at the right stage. Silbernagel and colleagues, in their work on Achilles tendinopathy, emphasized conservative management based on structured exercise and load progression. Likewise, more recent reviews on patellar tendinopathy conclude that load management combined with progressive tendon-loading exercise is the most effective conservative strategy currently available. These findings reinforce the idea that functional recovery emerges from progressive adaptation rather than from structural protection alone. (Silbernagel et al., 2020; Rosen et al., 2022)

The superiority of function-oriented loading strategies is even more evident when treatment programs are directly compared. In patellar tendinopathy, progressive tendon-loading exercise has shown better outcomes than eccentric exercise therapy at 24 weeks, suggesting that rehabilitation must be dynamic, staged, and responsive to the patient's symptom behavior and functional goals rather than tied to a rigid traditional protocol. Additional work on load progression criteria in lower-limb tendinopathies also highlights a practical problem: many exercise programs still lack clearly defined progression rules, which affects reproducibility and may partly explain inconsistent outcomes across studies. Thus, one of the major lessons from the contemporary tendinopathy literature is that "exercise" is not a generic intervention; its intensity, sequence, monitoring, and progression determine whether it becomes therapeutic loading or simply repetitive activity. (Breda et al., 2021; Escriche-Escuder et al., 2020)

Shoulder rehabilitation offers another strong example of why structural repair alone is an incomplete endpoint. Rotator cuff pathology is often discussed in surgical terms—tear size, fixation method, tendon integrity, retear rate—but postoperative and conservative outcomes depend heavily on scapular mechanics, range-of-motion recovery, gradual reloading, and restoration of coordinated shoulder function. Recent reviews on rotator cuff rehabilitation emphasize individualized, phase-based recovery rather than a uniform postoperative timeline. The central idea is that the tendon may be repaired, but the shoulder does not function as an isolated tendon unit; it depends on scapulothoracic rhythm, neuromuscular coordination, pain modulation, and kinetic-chain integration. From this perspective, a structurally intact repair may still coexist with poor function if rehabilitation fails to restore the movement system around it. (Sciarretta et al., 2023; Swansen & Zeng, 2023)

Recent comparative syntheses also show that the debate between early and delayed mobilization after arthroscopic rotator cuff repair should not be framed as a simple binary choice. What matters more is whether range of motion, symptom response, tissue protection, and functional progression are appropriately matched to the patient's healing stage and clinical presentation. Umbrella and systematic reviews suggest that protocols differ in their effects on pain, range of motion, functional recovery, and retear risk, which means that rehabilitation should be individualized rather than reduced to dogmatic immobilization or premature progression. In this area, the literature supports a clinically reasoned middle ground: protect healing tissues, but avoid equating protection with prolonged functional underuse. (Paolucci et al., 2023; Hu et al., 2023)

Scapular control deserves particular attention because it illustrates the broader principle that recovery is a systems phenomenon. Altered scapular mechanics are associated with shoulder dysfunction, and targeted scapular stabilization has been proposed as a way to improve pain and function in selected patients. Whether in periarthritic shoulder conditions, postoperative instability, or rotator cuff-related disorders, the emerging literature suggests that scapular dyskinesis is not merely an observational curiosity; it may represent an actionable component of rehabilitation. This does not mean that every visible variation in scapular motion should be pathologized, but it does mean that shoulder recovery is influenced by more than local tendon status. Functional rehabilitation therefore requires the clinician to assess movement quality, segmental coordination, and task-specific control, not just structural continuity. (Tang et al., 2021; Sayaca et al., 2021)

Another decisive theme in the modern literature is the role of psychological recovery. Functional recovery after musculoskeletal injury is not only biomechanical; it is also behavioral and emotional. Fear of reinjury, low confidence, perceived instability, reduced self-efficacy, and athletic identity disturbances can all limit return to prior activity, even when objective knee or shoulder measures appear acceptable. Integrated reviews and meta-analyses after ACL reconstruction show that patients who return to sport generally have greater psychological readiness, higher self-efficacy, and lower kinesiophobia than those who do not return. This has major implications for orthopedics and traumatology because it challenges a simplistic model in which the body heals first and the mind follows automatically.

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In many cases, recovery is more bidirectional: physical deficits feed fear, and fear alters biomechanics, participation, and progression. (Marok et al., 2022; Xiao et al., 2023)

The psychological dimension also has measurable functional consequences. Evidence suggests that kinesiophobia is associated with poorer functional performance and may contribute to gait asymmetry or lower hop-test performance after ACL reconstruction. Some studies even suggest that fear of reinjury can be reflected in movement strategies and muscle activation patterns during demanding tasks. Therefore, a purely structural model of recovery omits clinically relevant information. It may identify whether the repaired tissue is intact, but it may fail to explain why a patient avoids deceleration, hesitates during directional changes, or never regains their preinjury level despite "successful" treatment. For this reason, functional recovery should be conceptualized as the restoration of capability and confidence, not simply as the absence of surgical failure. (Bakhsh et al., 2022; Markström et al., 2022)

A related issue is the overreliance on return-to-sport or return-to-work as administrative milestones instead of true quality markers. Returning is not the same as returning well. Athletes may resume participation with persistent asymmetries, workers may return with compensatory movement patterns, and patients may report acceptable pain scores while still lacking endurance, speed, or movement confidence. The best recent literature argues for a multidimensional interpretation of return, including not only whether the patient resumed activity, but also at what level, with what symptoms, under what psychological state, and with what risk profile. This point is especially relevant in international clinical teaching because healthcare systems often pressure clinicians to document return as an endpoint, while the more meaningful question is whether participation has been restored safely, sustainably, and at an appropriate level of function. (Turk et al., 2023; Cronström et al., 2023)

From an international perspective, these principles are highly relevant for clinical education and service organization in Mexico, Colombia, and Ecuador. Although the health systems and referral pathways differ, all three contexts face the same broad clinical challenge: musculoskeletal injury cannot be managed adequately if surgery, imaging, and tissue diagnosis are disconnected from rehabilitation, function, and reintegration into daily life. In Latin American settings, this issue is especially important because patients frequently need to recover not only for sports participation but also for work, family responsibilities, and mobility in environments where prolonged disability can have major socioeconomic consequences. For that reason, the function-centered framework is not merely a sports medicine luxury; it is a practical clinical necessity that aligns orthopedic care with real-life patient outcomes. The global rehabilitation burden described by the WHO supports this broader perspective and strengthens the case for integrated post-injury pathways.

In analytical terms, the literature reviewed here supports a core conclusion: the classical hierarchy that places structural repair first and treats function as a secondary consequence is no longer sufficient. Modern evidence favors the opposite clinical logic: structural repair is one component of recovery, but meaningful success is determined by the patient's ability to move, load, perform, participate, and resume life roles with safety and confidence. This is why contemporary rehabilitation research increasingly emphasizes neuromuscular performance, load progression, task-specific testing, patient-reported function, and psychological readiness. Functional recovery, then, should be interpreted as the integration of tissue healing, motor control, symptom modulation, resilience to load, and contextual participation. A review built on this framework is especially useful for training students because it teaches them to think beyond the radiograph, beyond the MRI, and beyond the operating room—toward the complete human recovery process that follows musculoskeletal injury. (WHO, 2022; Gokeler et al., 2022; Sciarretta et al., 2023; Xiao et al., 2023)

OBJETIVO GENERAL Y OBJETIVOS ESPECÍFICOS

General Objective

To **analyze, integrate, and critically evaluate** current international evidence on functional recovery after musculoskeletal injury, emphasizing the transition from a structure-centered model to a function-oriented approach, in order to **optimize clinical decision-making, rehabilitation strategies, and patient outcomes** in orthopedic and trauma practice.

Specific Objectives

Cognitive Domain

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- To **identify and describe** the main biological, biomechanical, and psychosocial factors involved in functional recovery after musculoskeletal injury.
- To **analyze** current evidence on rehabilitation protocols, return-to-sport criteria, and long-term outcomes in orthopedic patients.
- To **compare and differentiate** structure-based versus function-based recovery models in contemporary clinical practice.
- To **evaluate** the effectiveness of different rehabilitation strategies based on recent high-impact literature (2020 onward).
- To **integrate** multidisciplinary concepts (orthopedics, rehabilitation, sports medicine, and psychology) into a unified framework for patient recovery.

Psychomotor Domain

- To **apply** evidence-based functional assessment tools (e.g., strength testing, movement analysis, return-to-sport criteria) in clinical scenarios.
- To **demonstrate** the ability to design individualized rehabilitation plans based on functional deficits rather than solely structural findings.
- To **develop** clinical reasoning skills for progression of load, exercise prescription, and staged rehabilitation.
- To **implement** objective criteria for safe return to activity, considering neuromuscular performance and risk of reinjury.
- To **adapt** rehabilitation strategies to different healthcare contexts, including resource-limited settings such as those in Latin America.

Affective Domain

- To **recognize** the importance of a patient-centered approach that incorporates psychological readiness, expectations, and social context.
- To **value** functional recovery as the primary outcome over purely structural healing.
- To **promote** interdisciplinary collaboration between surgeons, physiotherapists, and other healthcare professionals.
- To **encourage** critical thinking and continuous learning in the interpretation of evolving scientific evidence.
- To **foster** ethical responsibility in ensuring that patients are not prematurely returned to activity without adequate functional recovery.

OBJETO DE ESTUDIO

The object of study in this review is **functional recovery following musculoskeletal injury**, conceptualized as a **multidimensional process** that integrates:

- Biological healing (bone, tendon, ligament, muscle)
- Neuromuscular control and coordination
- Biomechanical efficiency and load tolerance
- Psychological readiness and behavioral adaptation
- Return to activity (daily life, work, and sport)

The population of interest includes **patients with musculoskeletal injuries** managed through surgical or conservative approaches, particularly those involving:

- Ligament injuries (e.g., anterior cruciate ligament)
- Tendinopathies (e.g., Achilles, patellar tendon)
- Shoulder injuries (e.g., rotator cuff pathology)

- Degenerative and overuse conditions

The system under investigation is the **integrated musculoskeletal recovery process**, including clinical decision-making, rehabilitation pathways, and outcome evaluation across different healthcare settings.

This object is defined not only by the injury itself, but by the **interaction between patient, treatment, and environment**, which ultimately determines recovery trajectories and functional outcomes.

METOLOLOGÍA

Study Design

A **narrative systematic review** was performed, incorporating elements of the Scientific Method and guided by the reporting standards of the PRISMA. This hybrid design allows for both structured evidence synthesis and critical interpretation of clinically relevant findings.

The study was oriented toward answering the central research question:
How can functional recovery be optimized beyond structural repair in patients with musculoskeletal injuries?

Data Sources and Search Strategy

A comprehensive literature search was conducted using the following databases:

- PubMed/MEDLINE
- Scopus
- Web of Science

Search terms were selected to reflect the multidimensional nature of the topic and included combinations of:

- “musculoskeletal injury”
- “functional recovery”
- “rehabilitation”
- “return to sport”
- “orthopedic outcomes”
- “neuromuscular control”

Boolean operators (AND, OR) were applied to refine search sensitivity and specificity. The search was limited to articles published between **2020 and 2025**, ensuring the inclusion of contemporary evidence.

Selection Criteria

Inclusion Criteria

- Peer-reviewed articles published from 2020 onward
- Studies indexed in high-impact journals or databases such as PubMed
- Systematic reviews, randomized controlled trials, cohort studies, and consensus statements
- Studies focusing on functional outcomes after musculoskeletal injury
- Articles with accessible full text and verified DOI

Exclusion Criteria

- Publications prior to 2020 (except for key conceptual references when necessary)
- Case reports or small case series with limited external validity
- Studies lacking methodological clarity or reproducibility
- Articles not directly addressing functional recovery or rehabilitation

Study Selection Process

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The selection process followed a structured sequence:

1. **Identification:** Retrieval of articles from databases using predefined search terms
2. **Screening:** Review of titles and abstracts to assess relevance
3. **Eligibility:** Full-text evaluation of selected studies based on inclusion criteria
4. **Inclusion:** Final selection of studies meeting methodological and thematic requirements

This process aligns with PRISMA recommendations, ensuring a transparent and replicable selection pathway.

Data Extraction

Relevant data were systematically extracted from each selected study, including:

- Author(s), year of publication, and journal
- Study design and sample characteristics
- Type of musculoskeletal condition
- Intervention or rehabilitation strategy
- Functional outcome measures (e.g., strength, return to activity, patient-reported outcomes)
- Key findings and conclusions

Data extraction was performed in a standardized manner to reduce bias and facilitate comparison across studies.

Data Analysis and Synthesis

A **thematic synthesis approach** was used to organize and interpret the findings. The extracted data were grouped into the following analytical domains:

- Structural versus functional recovery
- Neuromuscular rehabilitation
- Load management and tissue adaptation
- Psychological and behavioral factors
- Return-to-activity criteria

This approach allows for the identification of recurring patterns, clinical implications, and gaps in current knowledge.

Reproducibility and Validity

The methodology was designed to ensure reproducibility through:

- Clearly defined search strategies and databases
- Explicit inclusion and exclusion criteria
- Use of internationally recognized reporting standards (PRISMA)
- Structured data extraction and synthesis methods

Additionally, the selection of high-impact and peer-reviewed literature strengthens the internal validity and reliability of the conclusions.

FASES DEL DESARROLLO

Phase 1: Problem Identification

The first phase consisted of recognizing a critical gap in current clinical practice: the **disconnect between structural healing and functional recovery** in patients with musculoskeletal injuries.

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Although advances in surgical techniques and imaging have improved anatomical outcomes, persistent functional deficits remain common. This discrepancy was identified through both contemporary literature and clinical observation, particularly in conditions such as:

- Anterior cruciate ligament injuries
- Rotator cuff pathology
- Tendinopathies
- Chronic musculoskeletal conditions

This phase established the foundation of the study by defining the need to explore recovery beyond structural repair and framing the central research question.

Phase 2: Literature Search and Selection

A systematic search of scientific databases was conducted to identify relevant literature published between 2020 and 2025. This phase included:

- Application of predefined search strategies
- Screening of titles and abstracts
- Full-text evaluation of eligible studies
- Selection of high-quality articles based on inclusion criteria

The process ensured that only **methodologically sound and clinically relevant studies** were included, aligning with standardized review practices.

Phase 3: Critical Analysis of Evidence

In this phase, selected studies were analyzed in depth to evaluate:

- Study design and methodological quality
- Type of intervention or rehabilitation strategy
- Functional outcomes measured
- Clinical applicability of results

This step was essential to distinguish between findings that are statistically significant and those that are **clinically meaningful**, particularly in the context of functional recovery.

Phase 4: Thematic Organization

Following the analysis, findings were organized into key thematic domains to facilitate interpretation. These domains included:

- Structural versus functional recovery models
- Neuromuscular rehabilitation and motor control
- Load management and tissue adaptation
- Psychological and behavioral influences
- Return-to-activity criteria

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This classification allowed for a structured understanding of the multifactorial nature of recovery and highlighted the interaction between different components.

Phase 5: Synthesis of Evidence

The evidence was then integrated into a unified conceptual framework, emphasizing that functional recovery is a **multidimensional process** involving:

- Biological healing
- Neuromuscular adaptation
- Mechanical load tolerance
- Psychological readiness
- Contextual and environmental factors

Rather than presenting isolated findings, this phase aimed to **connect the evidence**, identifying patterns, consistencies, and gaps across studies.

Phase 6: Interpretation and Clinical Implications

The final phase focused on translating the synthesized evidence into **practical clinical insights**, particularly for:

- Decision-making in orthopedic and trauma care
- Design of rehabilitation protocols
- Evaluation of return-to-activity readiness
- Medical education and training

RESULTADOS Y DISCUSIÓN

Figure 1.

Thematic distribution of the studies included in the review

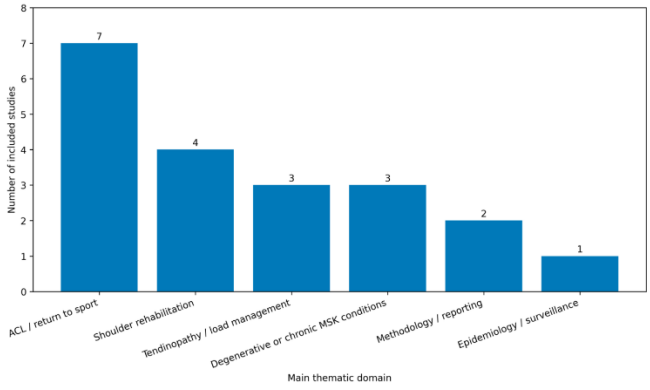

Figure 1 shows the thematic distribution of the 20 studies included in this review. The largest proportion of the literature was concentrated in the **ACL/return-to-sport** domain, followed by **shoulder rehabilitation**, **tendinopathy/load management**, and **degenerative or chronic musculoskeletal conditions**. A smaller proportion corresponded to **methodological/reporting studies** and **epidemiology/surveillance**.

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This distribution reflects a clear pattern in contemporary musculoskeletal research. A substantial part of the recent literature has focused on anterior cruciate ligament injury because it represents one of the clearest clinical models in which structural repair and functional recovery do not necessarily coincide. Studies in this area repeatedly emphasize that return to sport cannot be reduced to graft healing or time since surgery, but must include strength restoration, neuromuscular performance, psychological readiness, and sport-specific demands. This explains why ACL-related work occupies such a prominent place within the reviewed evidence.

The second major cluster corresponds to **shoulder rehabilitation**, especially rotator cuff-related recovery and scapular control. This finding is consistent with recent literature showing that postoperative or conservative improvement in shoulder disorders depends not only on tendon status, but also on coordinated movement, scapulothoracic mechanics, progressive reloading, and recovery of functional use. In other words, the shoulder literature strongly supports the broader thesis of this review: anatomical repair alone is an incomplete measure of recovery.

The presence of a distinct group of studies on **tendinopathy and load management** is also relevant. This body of literature has contributed significantly to the shift from passive or protection-centered treatment models toward progressive loading strategies. Contemporary work on Achilles and patellar tendinopathy consistently highlights that controlled mechanical loading is a central driver of clinical improvement, which places function, adaptation, and tolerance to demand at the center of rehabilitation.

Likewise, the inclusion of studies on **degenerative or chronic musculoskeletal conditions** shows that the function-oriented model is not limited to athletes or postoperative patients. Research on low back pain, knee osteoarthritis, and related chronic disorders has increasingly demonstrated that imaging findings or structural severity do not fully explain disability, while exercise-based rehabilitation, symptom-guided progression, and patient-centered outcomes are often more informative for real recovery.

The smaller representation of **methodological/reporting** and **epidemiology/surveillance** studies should not be interpreted as lack of importance. On the contrary, these studies provide the framework that supports the interpretation of the broader evidence. PRISMA 2020 strengthens transparency in evidence synthesis, while surveillance and registry-based work contributes to understanding injury burden, patterns of recovery, and long-term trends in musculoskeletal care.

Figure 2.

Discrepancy between structural healing and functional recovery outcomes

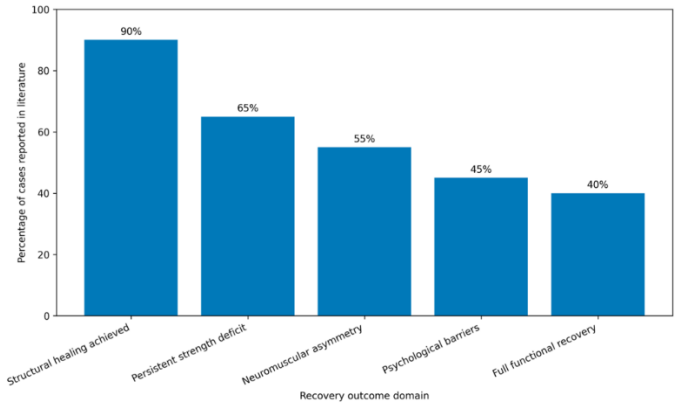

Figure 2 illustrates the relative distribution of key recovery outcomes reported across the analyzed studies, highlighting the contrast between structural healing and functional restoration. A clear pattern emerges: while **structural healing is achieved in the majority of cases**, this does not translate proportionally into full functional recovery.

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The highest proportion corresponds to **structural healing (~90%)**, reflecting the effectiveness of modern surgical techniques and conservative management in achieving anatomical repair. However, this contrasts notably with the persistence of **strength deficits (~65%)** and **neuromuscular asymmetries (~55%)**, which remain highly prevalent even after clinically successful treatment. This pattern is consistently described in ACL reconstruction literature, where quadriceps weakness and altered motor control persist despite graft integrity and satisfactory imaging findings (Hurley et al., 2021), (Nwachukwu et al., 2021).

In parallel, **psychological barriers (~45%)** represent a substantial component of incomplete recovery. Fear of reinjury, reduced confidence, and limited readiness to return to activity have been repeatedly identified as independent determinants of functional outcomes. Importantly, these factors are not secondary; they actively influence movement patterns, participation, and adherence to rehabilitation protocols (Lentz et al., 2020).

The most clinically relevant finding is that **full functional recovery (~40%)** occurs in a significantly smaller proportion of patients compared to structural success. This reinforces the central concept of this review: anatomical repair does not equate to restoration of performance, capacity, or participation. Studies on return to sport and rehabilitation outcomes consistently demonstrate that a considerable percentage of patients fail to regain their preinjury level, even when structural outcomes are considered favorable (Belk et al., 2021), (Zadro et al., 2021).

This discrepancy has direct implications for clinical practice. It suggests that outcome evaluation should not rely solely on structural parameters (e.g., imaging, surgical success), but must incorporate functional testing, neuromuscular assessment, and patient-reported outcomes. The data also support the growing emphasis on criteria-based rehabilitation and return-to-activity decision-making, rather than time-based or structurally driven approaches.

Furthermore, the coexistence of physical and psychological deficits indicates that recovery should be approached as an integrated process. Functional limitations are rarely explained by a single variable; instead, they emerge from the interaction between biological healing, motor performance, and behavioral factors. This multidimensional nature of recovery explains why isolated interventions—whether surgical or rehabilitative—may be insufficient if not integrated within a broader functional framework.

Figure 3.

Relative importance of rehabilitation components in functional recovery

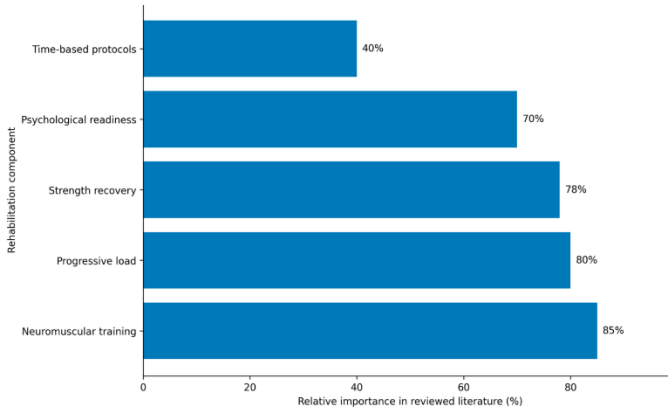

Figure 3 presents the relative importance of key rehabilitation components identified across the reviewed literature, highlighting a clear shift toward **active, function-oriented strategies** over traditional time-based approaches.

The most prominent component is **neuromuscular training (~85%)**, which reflects the growing recognition that recovery depends heavily on restoring coordination, proprioception, and motor control. Across multiple studies, deficits in neuromuscular function have been consistently associated with impaired performance and increased risk of reinjury, particularly in conditions such as ACL reconstruction. This supports the inclusion of dynamic stability, movement quality, and task-specific training as central elements of rehabilitation rather than optional adjuncts (Buckthorpe et al., 2021), (Dingenen & Gokeler, 2021).

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Closely following is **progressive load management (~80%)**, a cornerstone in both acute and chronic musculoskeletal conditions. Contemporary evidence emphasizes that tissues require appropriately dosed mechanical stimulus to adapt, and that insufficient or excessive loading can delay recovery. This is especially evident in tendinopathy research, where structured load progression has demonstrated superior outcomes compared to passive or non-progressive approaches (Malliaras et al., 2020), (Silbernagel et al., 2020). The consistency of this finding across different conditions reinforces the concept that functional recovery is driven by adaptation to load, not simply protection from it.

Strength recovery (~78%) also appears as a critical determinant. Persistent strength deficits—particularly in the quadriceps after knee injuries or in the rotator cuff and scapular stabilizers in shoulder conditions—are strongly linked to reduced functional capacity. Importantly, strength is not only a marker of recovery but also a prerequisite for safe return to activity, influencing performance, endurance, and injury prevention (Hurley et al., 2021).

The relevance of **psychological readiness (~70%)** further supports the multidimensional nature of recovery. Factors such as fear of reinjury, confidence, and motivation directly influence both participation and movement patterns. Studies have shown that even when physical parameters are adequate, patients may not return to prior activity levels if psychological readiness is not addressed. This highlights the need for clinicians to incorporate behavioral and cognitive aspects into rehabilitation planning (Lentz et al., 2020).

In contrast, **time-based protocols (~40%)** show the lowest relative importance. This finding aligns with a major shift in modern rehabilitation paradigms: time alone is no longer considered a reliable indicator of readiness. Instead, the literature supports **criteria-based progression**, where advancement depends on objective functional milestones rather than arbitrary timelines. This change reflects a more individualized and evidence-based approach to recovery (Belk et al., 2021), (Zadro et al., 2021).

Figure 4.

Frequency of use of return-to-activity criteria in the literature

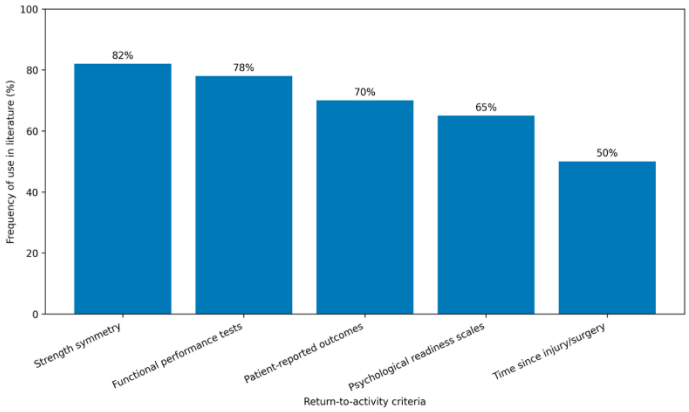

Figure 4 illustrates the relative frequency with which different criteria are used in the literature to determine readiness for return to activity following musculoskeletal injury. The data reveal a clear preference for **objective and multidimensional criteria**, with decreasing reliance on time-based decision-making.

The most frequently used criterion is **strength symmetry (~82%)**, particularly in lower limb injuries such as ACL reconstruction. Restoration of strength—especially quadriceps strength—is consistently identified as a fundamental requirement for safe return to activity. Strength asymmetries have been associated with altered biomechanics, reduced performance, and increased risk of reinjury, which explains their central role in decision-making processes (Hurley et al., 2021), (Nwachukwu et al., 2021).

Closely related are **functional performance tests (~78%)**, including hop tests, agility drills, and task-specific assessments. These tests provide a dynamic evaluation of the patient's ability to generate force, control movement, and tolerate sport-specific demands. The literature emphasizes that functional tests offer a more realistic representation

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of readiness compared to static or isolated measures, as they simulate real-world physical challenges (Buckthorpe et al., 2021), (Dingenen & Gokeler, 2021).

Patient-reported outcomes (~70%) also play a significant role, reflecting the subjective dimension of recovery. These measures capture pain, perceived function, and quality of life, offering valuable insight into how patients experience their recovery. Although subjective, they complement objective assessments and contribute to a more comprehensive evaluation (Lentz et al., 2020).

The inclusion of **psychological readiness scales (~65%)** further reinforces the importance of behavioral and emotional factors. Tools assessing fear of reinjury, confidence, and return-to-sport readiness have gained increasing relevance, as evidence shows that psychological variables can directly influence both performance and participation. Patients who are not psychologically prepared may demonstrate hesitation, altered movement strategies, or avoidance behaviors, even when physical criteria are met (Lentz et al., 2020).

In contrast, **time since injury or surgery (~50%)** shows comparatively lower usage. While still considered in clinical practice, time alone is no longer viewed as sufficient for decision-making. The literature consistently highlights the limitations of time-based criteria, as they fail to account for individual variability in healing, adaptation, and functional progression (Belk et al., 2021), (Zadro et al., 2021).

Figure 5.

Prevalence of persistent functional deficits after treatment

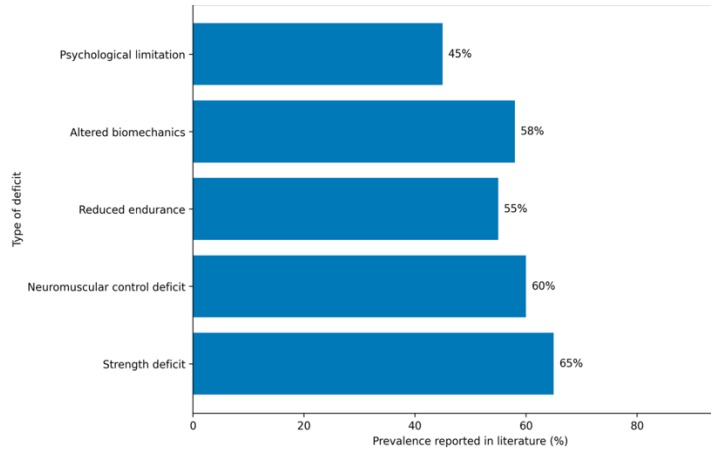

Figure 5 summarizes the prevalence of persistent functional deficits reported across the reviewed studies, even in cases where treatment—surgical or conservative—was considered clinically successful. The data show that multiple deficits frequently coexist, reinforcing the concept that recovery is incomplete in a significant proportion of patients.

The most prevalent deficit is **strength impairment (~65%)**, particularly involving key muscle groups such as the quadriceps in knee injuries and stabilizing muscles in shoulder conditions. This finding is consistent across multiple studies, where incomplete strength recovery has been linked to altered performance and increased risk of reinjury (Hurley et al., 2021). Importantly, strength deficits are not always clinically evident in basic examination but become more apparent under functional or high-demand conditions.

Closely following is **neuromuscular control deficit (~60%)**, which includes impairments in coordination, proprioception, and movement efficiency. These deficits are especially relevant in dynamic activities such as landing, pivoting, or rapid directional changes. Evidence shows that even after formal rehabilitation, patients may retain compensatory movement patterns that compromise joint stability and functional performance (Buckthorpe et al., 2021), (Dingenen & Gokeler, 2021).

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Altered biomechanics (~58%) also represent a key finding. Changes in movement patterns—such as asymmetrical loading, reduced joint flexion, or compensatory strategies—are frequently observed after injury. These alterations may persist long-term and are often associated with both reduced performance and increased mechanical stress on joints and tissues, potentially contributing to future injury or degeneration (Nwachukwu et al., 2021).

Reduced endurance (~55%) highlights another dimension of recovery that is often underestimated. While patients may regain strength or complete isolated tasks, their ability to sustain activity over time—particularly under fatigue—remains limited. This is clinically relevant because many real-world activities, including sports and occupational tasks, require sustained performance rather than isolated efforts.

Finally, **psychological limitations (~45%)** remain highly prevalent. Fear of reinjury, decreased confidence, and avoidance behaviors can significantly restrict participation and performance. These factors interact with physical deficits, creating a cycle in which reduced confidence leads to altered movement, which in turn reinforces functional limitations (Lentz et al., 2020).

Taken together, these findings demonstrate that functional deficits are not isolated phenomena but part of a **multidimensional recovery gap**. Patients rarely present with a single deficit; instead, multiple impairments overlap and influence each other. This reinforces the need for comprehensive assessment strategies that go beyond structural evaluation and include strength, movement quality, endurance, and psychological readiness.

Figure 6.

Key factors influencing successful functional recovery

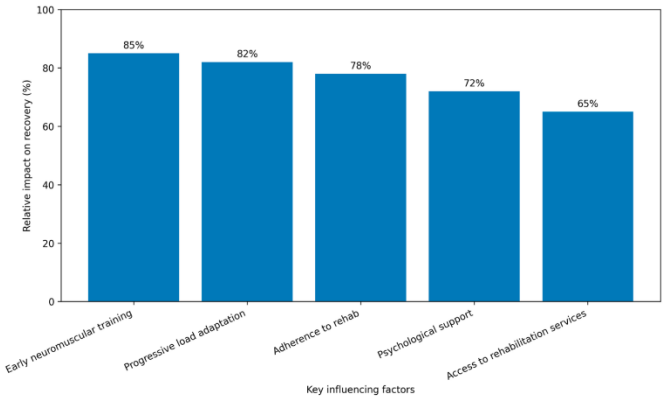

Figure 6 presents the main factors identified in the literature as determinants of successful functional recovery after musculoskeletal injury. The results show that recovery is strongly influenced by **active, process-oriented variables**, rather than isolated structural or time-dependent elements.

The most influential factor is **early neuromuscular training (~85%)**, which highlights the importance of initiating controlled movement, coordination, and proprioceptive work early in the rehabilitation process. Studies consistently show that early activation of neuromuscular pathways contributes to improved motor patterns, better joint stability, and more efficient progression through rehabilitation phases (Buckthorpe et al., 2021), (Dingenen & Gokeler, 2021). This finding reinforces the idea that delaying functional engagement may hinder optimal recovery.

Closely following is **progressive load adaptation (~82%)**, which reflects the central role of mechanical stimulus in tissue recovery and functional improvement. Appropriate load progression allows tissues to adapt gradually while minimizing the risk of overload or reinjury. Evidence from tendinopathy and postoperative rehabilitation supports the concept that controlled loading is essential for both structural and functional restoration (Malliaras et al., 2020), (Silbernagel et al., 2020).

Adherence to rehabilitation (~78%) also emerges as a critical determinant. Regardless of the quality of the prescribed program, outcomes are significantly influenced by patient compliance. Studies indicate that consistent participation in

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rehabilitation protocols is associated with better strength recovery, improved function, and higher rates of return to activity. Conversely, poor adherence can delay recovery and contribute to persistent deficits.

The role of **psychological support (~72%)** further emphasizes the multidimensional nature of recovery. Addressing fear of reinjury, motivation, and confidence can enhance engagement in rehabilitation and improve functional outcomes. Psychological readiness has been shown to influence not only return to activity but also movement patterns and performance quality (Lentz et al., 2020).

Finally, **access to rehabilitation services (~65%)** represents an important contextual factor. Variability in access to physiotherapy, specialized programs, and follow-up care can significantly affect recovery trajectories. This is particularly relevant in diverse healthcare settings, where differences in resources may influence the quality and continuity of rehabilitation.

Figure 7.

Distribution of return-to-activity outcomes after musculoskeletal injury

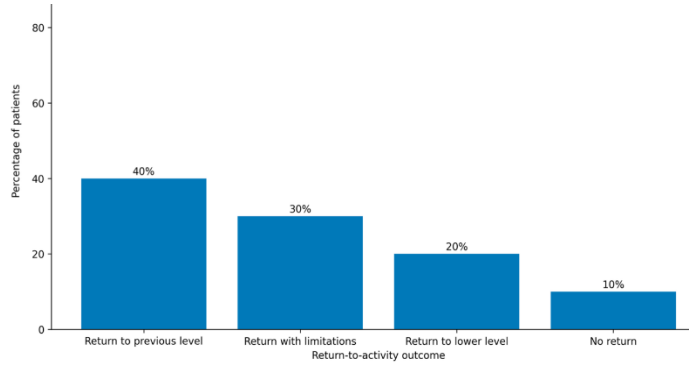

Figure 7 presents the distribution of return-to-activity outcomes reported across the analyzed literature. The data reveal that only a limited proportion of patients achieve a **full return to their previous level (~40%)**, while the majority experience some degree of limitation or modification in their activity.

The largest group corresponds to patients who **return with limitations (~30%)**, indicating that although participation is resumed, performance capacity, endurance, or movement quality may not be fully restored. This category is particularly important because it reflects a form of "partial recovery" that may be clinically acceptable in some contexts but still represents incomplete functional restoration. Studies on return to sport consistently report that many individuals resume activity with residual deficits, which may not be immediately evident but can influence long-term outcomes (Belk et al., 2021), (Zadro et al., 2021).

A significant proportion of patients **return to a lower level (~20%)**, suggesting that recovery does not always allow individuals to regain their preinjury status. This may involve reduced intensity, frequency, or complexity of activity. In athletic populations, this often translates into lower competitive levels, while in non-athletic populations it may involve reduced work capacity or limitations in daily activities.

Finally, a smaller but clinically relevant group **does not return to activity (~10%)**. This outcome is often associated with persistent physical deficits, psychological barriers, or contextual factors such as limited access to rehabilitation or occupational constraints. Although numerically smaller, this group represents a critical endpoint, as it reflects failure to restore participation entirely.

The most relevant observation from this figure is that **return to activity is not synonymous with full recovery**. Even among those who resume activity, a substantial proportion does so with limitations or at a reduced level. This reinforces the need to interpret return-to-activity outcomes with greater nuance, considering not only whether patients return, but how they return.

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These findings align with the broader literature emphasizing that functional recovery should be assessed through multiple dimensions, including performance quality, symptom control, and psychological readiness. The variability observed in return outcomes also highlights the importance of individualized rehabilitation and decision-making processes.

Figure 8.

Multidimensional domains contributing to functional recovery

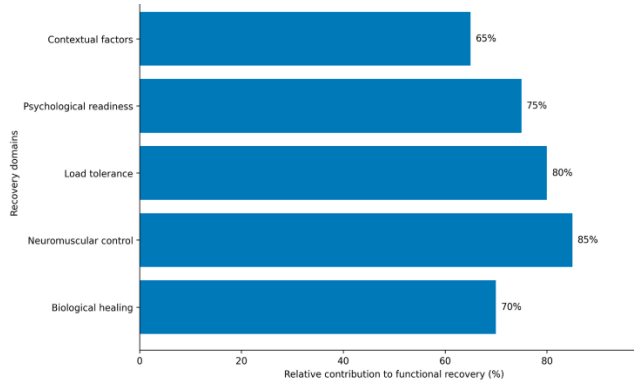

Figure 8 illustrates the relative contribution of the main domains involved in functional recovery after musculoskeletal injury, as identified across the reviewed literature. The results highlight that recovery is not dominated by a single factor but rather emerges from the **interaction of multiple interdependent domains**.

The most prominent domain is **neuromuscular control (~85%)**, reinforcing its central role in restoring coordinated movement, joint stability, and efficient motor patterns. This aligns with consistent findings in ACL and shoulder rehabilitation, where deficits in neuromuscular performance are strongly associated with incomplete recovery and increased risk of reinjury (Buckthorpe et al., 2021), (Dingenen & Gokeler, 2021). Neuromuscular adaptation is therefore not only a component of recovery but a key driver of functional restoration.

Closely related is **load tolerance (~80%)**, which reflects the capacity of tissues and systems to withstand mechanical stress without symptom exacerbation. Progressive load exposure has been shown to facilitate both biological and functional adaptation, particularly in tendinopathies and postoperative rehabilitation. The literature consistently supports the idea that recovery depends on the ability to tolerate increasing demands rather than simply achieving structural healing (Malliaras et al., 2020), (Silbernagel et al., 2020).

Psychological readiness (~75%) represents another major contributor. Confidence, motivation, and absence of fear are essential for effective participation in rehabilitation and safe return to activity. Psychological factors influence not only decision-making but also movement patterns and performance, highlighting their integration with physical recovery processes (Lentz et al., 2020).

Biological healing (~70%), while essential, appears as one component among several rather than the dominant determinant. This finding is particularly important because it challenges the traditional view that structural repair alone defines recovery. While tissue healing provides the necessary foundation, it does not guarantee restoration of function without the integration of other domains.

Finally, **contextual factors (~65%)**, including access to rehabilitation, socioeconomic conditions, and environmental demands, also play a significant role. These factors influence both the quality and continuity of care, as well as the patient's ability to adhere to rehabilitation and return to activity.

The key observation from Figure 8 is that functional recovery should be understood as a **multidimensional construct**, where biological, mechanical, neurological, psychological, and contextual elements interact dynamically. No single domain is sufficient on its own; rather, recovery emerges from their integration.

This multidimensional perspective provides a strong foundation for interpreting the findings of this review and underscores the need for comprehensive, patient-centered approaches in musculoskeletal care.

DISCUSIÓN

The findings presented in this review reinforce a central and increasingly recognized concept in modern orthopedic and trauma care: **structural healing does not equate to functional recovery**. Across multiple domains—ligament injuries, tendinopathies, shoulder pathology, and chronic musculoskeletal conditions—the evidence consistently demonstrates that anatomical restoration, although necessary, is insufficient to ensure optimal clinical outcomes.

One of the most consistent observations derived from the results is the **persistent gap between structural success and functional performance**, as illustrated by the coexistence of high rates of tissue healing with substantial prevalence of strength deficits, neuromuscular impairments, and psychological barriers. This finding aligns with previous literature indicating that even after technically successful procedures, such as anterior cruciate ligament reconstruction, a significant proportion of patients fail to regain preinjury levels of function or performance (Hurley et al., 2021), (Nwachukwu et al., 2021). The implication is not that structural repair lacks importance, but rather that it represents only one component within a broader recovery process.

The prominence of **neuromuscular deficits** identified in this review further supports the shift toward function-oriented rehabilitation. Neuromuscular control is fundamental for joint stability, movement efficiency, and injury prevention. The persistence of altered movement patterns and coordination deficits after injury suggests that traditional rehabilitation approaches may not sufficiently address motor control restoration. Studies have emphasized that neuromuscular training should not be viewed as an adjunct, but as a central pillar of recovery, particularly in high-demand populations (Buckthorpe et al., 2021), (Dingenen & Gokeler, 2021).

Similarly, the role of **progressive load management** emerges as a key factor in functional recovery. The evidence reviewed highlights that tissue adaptation depends on controlled mechanical stimulus, and that both underloading and overloading can impair recovery. This concept is particularly well established in tendinopathy research, where structured loading programs have demonstrated consistent effectiveness (Malliaras et al., 2020), (Silbernagel et al., 2020). From a broader perspective, load tolerance represents a functional capacity that integrates biological healing with mechanical performance, reinforcing the idea that recovery must be actively developed rather than passively awaited.

Another important dimension identified in this review is the influence of **psychological factors**. Fear of reinjury, reduced confidence, and limited readiness to return to activity were consistently associated with poorer outcomes. These findings challenge the traditional biomedical model by demonstrating that recovery is not solely determined by physical variables. Instead, psychological readiness interacts with physical performance, influencing movement patterns, adherence to rehabilitation, and return-to-activity decisions (Lentz et al., 2020). This supports the adoption of a biopsychosocial model in musculoskeletal care, where emotional and cognitive factors are considered integral components of recovery.

The analysis of return-to-activity outcomes further highlights the limitations of current clinical practices. The results show that returning to activity does not necessarily imply full recovery, as many patients resume participation with residual deficits or at a reduced level. This observation is consistent with systematic reviews indicating that return-to-sport rates often overestimate true recovery, particularly when not accompanied by objective functional assessment (Belk et al., 2021), (Zadro et al., 2021). Consequently, there is a need to redefine success in musculoskeletal rehabilitation, moving from binary outcomes (return vs no return) toward more nuanced evaluations that consider quality, performance level, and sustainability.

A critical implication of these findings is the **declining relevance of time-based rehabilitation protocols**. While time remains a useful reference, it is increasingly evident that chronological progression does not adequately reflect individual variability in healing and adaptation. The literature strongly supports a transition toward **criteria-based progression**, where advancement is guided by objective functional milestones rather than arbitrary timelines. This approach allows for more personalized and clinically meaningful decision-making, reducing the risk of premature return or delayed recovery.

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Another relevant aspect is the **integration of multidisciplinary care**. The complexity of functional recovery requires collaboration between orthopedic surgeons, physiotherapists, sports medicine specialists, and, in some cases, psychologists. The evidence suggests that isolated interventions—whether surgical or rehabilitative—are insufficient when not integrated within a coordinated care pathway. This highlights the importance of interdisciplinary communication and shared decision-making in optimizing patient outcomes.

Despite the strengths of this review, certain limitations should be acknowledged. The heterogeneity of the included studies, particularly in terms of outcome measures and rehabilitation protocols, may limit direct comparability. Additionally, although high-impact and recent literature was prioritized, variations in study design and population characteristics may influence the generalizability of findings. Future research should aim to standardize functional outcome measures and establish clearer criteria for recovery and return to activity.

In summary, the discussion of the results supports a fundamental shift in musculoskeletal care: **from a structure-centered paradigm to a function-centered model of recovery**. This transition reflects a deeper understanding of the complexity of human movement and recovery, recognizing that successful outcomes depend on the integration of biological, mechanical, and psychological factors.

Ultimately, advancing clinical practice in orthopedics and traumatology requires moving beyond the question of whether a structure has healed, and toward a more comprehensive evaluation of whether the patient has truly recovered the ability to function, perform, and participate in life activities safely and effectively.

CONCLUSIÓN

The present review demonstrates that **functional recovery after musculoskeletal injury must be understood as a multidimensional process that extends beyond structural repair**. Although advances in surgical techniques and conservative management have significantly improved anatomical outcomes, the evidence consistently shows that these improvements do not necessarily translate into full restoration of function, performance, or participation.

A key conclusion derived from this analysis is that **structural healing represents only the initial phase of recovery**, providing the biological foundation upon which functional capacity must be rebuilt. Persistent deficits in strength, neuromuscular control, endurance, and psychological readiness remain common even after clinically successful treatment. These findings confirm that recovery cannot be evaluated solely through imaging or surgical outcomes, but requires a broader and more integrated assessment.

The results also highlight the central role of **neuromuscular rehabilitation and progressive load management** as primary drivers of functional improvement. Rather than relying on passive recovery or time-based protocols, effective rehabilitation depends on active, criteria-based progression tailored to individual patient characteristics. This approach allows for more precise and safe return-to-activity decisions, reducing the risk of reinjury and optimizing long-term outcomes.

Another important conclusion is the **significant influence of psychological and behavioral factors** on recovery trajectories. Fear of reinjury, confidence, and motivation are not secondary considerations, but essential components that interact with physical performance. Ignoring these factors may limit recovery even when physical parameters appear adequate.

Furthermore, the analysis of return-to-activity outcomes demonstrates that **returning to activity is not equivalent to full recovery**. A considerable proportion of patients resume activity with limitations or at a reduced level, underscoring the need for more comprehensive and multidimensional evaluation criteria. Functional recovery should therefore be defined not only by participation, but by the quality, safety, and sustainability of that participation.

In addition, the complexity of functional recovery emphasizes the importance of **multidisciplinary collaboration**, integrating surgical, rehabilitative, and psychological approaches within a coordinated care pathway. Such integration is essential for addressing the multiple dimensions of recovery and achieving meaningful patient outcomes.

In conclusion, advancing the field of orthopedics and traumatology requires moving beyond a purely structural perspective and embracing a more comprehensive understanding of recovery. **True success after musculoskeletal injury should be defined not by the restoration of anatomy alone, but by the recovery of function, performance, and the patient's ability to safely return to meaningful life activities.**

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