Effectiveness of rehabilitation programs for common sports injuries: a systematic review and meta-analysis

Efectividad de los programas de rehabilitación para lesiones deportivas comunes: una revisión sistemática y metanálisis

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Abstract

Background: Injuries related to sports are very common among athletes; they result in functional impairments and require a long recovery duration. Rehabilitation programs have a potential role in facilitating return to sports. Several rehabilitation modalities, including balance training, strength training, and hop-based exercises, have been studied extensively, but their effectiveness remains debated. The objective of this analysis was to assess the effectiveness of different rehabilitation programs for common lower limb injuries (LLIs).
Methods: This work analyzed the data from randomized controlled trials (RCTs) obtained from peer-reviewed journals. Eligible trials were those that reported rehabilitation interventions for LLIs and assessed functional performance, balance, and strength outcomes. The I^2 statistics were used to estimate the heterogeneity, whereas the random-effect tool was applied for the meta-analysis.
Results: Balance training considerably improved Y-Balance Test (YBT) scores ($p < 0.001$), especially in posteromedial and posterolateral reach distances. Substantial improvements in performance were discovered based on Hop-based modality, where the subjects who underwent reconstruction experienced potential improvements in triple and single tests($p < 0.001$). Neuromuscular control was enhanced through the implementation of strength interventions, with remarkable improvement in hip abduction and strength of external rotation ($p < 0.001$). The studies of balance training revealed a heterogeneity ($I^2 = 95.6\%$), which suggested variability in adherence, duration, and intensity of the intervention.
Conclusion: Rehabilitation programs for Common Sports Injuries resulted in the most effective functional recovery outcomes for lower limb sports injuries.

Keywords

Effectiveness; rehabilitation; outcomes.

Resumen

Antecedentes: Las lesiones relacionadas con el deporte son muy comunes entre los atletas; resultan en impedimentos funcionales y requieren una larga duración de recuperación. Los programas de rehabilitación tienen un papel potencial para facilitar el regreso a los deportes. Varias modalidades de rehabilitación, incluido el entrenamiento del equilibrio, el entrenamiento de fuerza y los ejercicios basados en saltos, se han estudiado ampliamente, pero su efectividad sigue siendo objeto de debate. El objetivo de este análisis fue evaluar la efectividad de diferentes programas de rehabilitación para lesiones comunes de miembros inferiores (LLI).
Métodos: Este trabajo analizó los datos de ensayos controlados aleatorios (ECA) obtenidos de revistas revisadas por pares. Los ensayos elegibles fueron aquellos que informaron intervenciones de rehabilitación para LLI y evaluaron los resultados del rendimiento funcional, el equilibrio y la fuerza. La estadística I2 se utilizó para estimar la heterogeneidad, mientras que la herramienta de efectos aleatorios se aplicó para el metanálisis.
Resultados: El entrenamiento del equilibrio mejoró considerablemente las puntuaciones de la Prueba de Equilibrio Y (YBT) ($p < 0{,}001$), especialmente en distancias de alcance posteromedial y posterolateral. Se descubrieron mejoras sustanciales en el rendimiento basadas en la modalidad basada en Lúpulo, donde los sujetos que se sometieron a reconstrucción experimentaron mejoras potenciales en pruebas triples y únicas ($p < 0{,}001$). El control neuromuscular se mejoró mediante la implementación de intervenciones de fuerza, con una mejora notable en la abducción de la cadera y la fuerza de rotación externa ($p < 0{,}001$). Los estudios de entrenamiento del equilibrio revelaron una heterogeneidad (I2 = 95,6%), lo que sugirió variabilidad en la adherencia, duración e intensidad de la intervención.
Conclusión: Los programas de rehabilitación para Lesiones Deportivas Comunes dieron como resultado los resultados de recuperación funcional más efectivos para las lesiones deportivas de las extremidades inferiores.

Palabras clave

Efectividad; rehabilitación; resultados.

Introduction

Sports injuries are common injuries among athletes across all performance levels due to the physical demands of competition, performance, and training overload (Kaur et al, 2025). Sports injuries affect amateur and elite athletes as well as the healthcare delivery and public health (Takáč, 2025). Such injuries account for 20-40% of the musculoskeletal clinic visits, globally, especially among those who are engaged in high-intensity sports and are increasingly frequent due to rising participation in professional and amateur athletics (Arvinen-Barrow et al, 2014; Scanaliato et al, 2021).

Sports injuries most often affect the lower and upper limbs (Scanaliato et al, 2021). Such injuries range from minor strains and sprains to more severe injuries such as fractures or tears, which impair physical performance and considerably impact the social identity, physiological health, and long-term career of the athletes (Griffin et al, 2006), (de Sire et al, 2025).

Physiotherapy focuses on improving symptoms and gaining neuromuscular control, function, and strength, with a reduction of re-injury risk via tailored interventions (Forelli et al, 2024). Hence, restoring the full function, preventing recurrence, and addressing the psychological ramifications of being sidelined should be achieved through effective rehabilitation (Kaur et al, 2025).

Nonetheless, classical strategies of rehabilitation often focused on physiotherapy alone; this is no longer suitable or adequate to meet the requirements of today's athletes (Kaur et al, 2025). Variations have been recorded for approaches of rehabilitation regarding sports injuries (Kuhn et al, 2021). Also, other variations have been reported in treatment pathways (Pilkington et al, 2021). Therefore, it is crucial to determine which modality resulted in potential improvements in strength, injury prevention, and functional performance of those affected by sports injury, especially the affected lower limb to help determine the best modality for best outcomes. The aim of this work was to determine the efficiency of rehabilitation approaches for LLIs through the analysis of data from RCTs. Also, this research tries to determine the most effective strategies for reducing re-injury risk and achieving recovery.

Method

Study design

This meta-analysis synthesizes quantitative data from RCTs to provide a comprehensive assessment of intervention outcomes.

The following Prisma guidelines Eligibility Criteria were conducted:

The trials included in this analysis met the criteria:

- RCTs investigate rehabilitation programs for lower limb sports injuries.
- Clear reporting of data.
- Articles from peer-reviewed journals.
- Trials that compare rehabilitation interventions with either control groups or alternative treatments.
- Studies with follow-up durations of at least four weeks.

Data Sources and Search Strategy

A search procedure was performed through databases during the first quarter of 2025, including "PubMed, Scopus, Web of Science, and Cochrane Library". The search strategy utilized a combination of Medical Subject Headings (MeSH) terms and keywords such as "sports injury rehabilitation," "balance training," "strength training," "neuromuscular control, "Y-Balance Test," functional performance," and "lower limb injuries." The search was restricted to English studies .

Study Selection and Data Extraction

Two independent authors screened titles and abstracts for relevance. The articles were then selected based on the determined criteria. Any conflicts were solved via a third author. Extraction of the data involved the following:

Trial characteristics

Approach details.

Comparison categories

Outcome measures

Follow-up duration and post-intervention outcomes.

Intervention Characteristics

The rehabilitation interventions examined in the included studies were classified into the following categories: (Livneh, 1989)

- Balance Training: Including wobble board training, whole-body vibration therapy (WBVT), and progressive proprioceptive exercises.
- Strength-Based approach: Resistance band, hip strengthening, and neuromuscular facilitation exercises.
- Hop-Based intervention: Hop-to-stabilization drills, single-leg balance exercises.
- Post-Operative approach: following ACL reconstruction.

Outcome Measures

- Balance Performance: Y-Balance Test (YBT), Star Excursion Balance Test (SEBT), and Balance Error Scoring System (BESS).
- Functional Performance: Hop tests (single hop, triple hop, figure-of-eight hop, side hop).
- Strength evaluation: Isometric strength, hip abduction, and external rotation strength.
- Patient Outcomes: Foot and Ankle Outcome Score (FAOS), Foot and Ankle Ability Measure (FAAM-Sport).

Statistical Analysis

Meta-analysis was established using a random-effects model to estimate variability across studies. Standardized mean differences (SMD) and 95% confidence intervals (CIs) were computed for each outcome measure. Heterogeneity was evaluated using I^2 statistics, with values >50% referring to potential heterogeneity. Sensitivity analyses were carried out to assess the robustness of results (Kaptein, 2022)

Risk of Bias Assessment

The methodological quality of RCTs was estimated using the "Cochrane Risk of Bias (ROB 2)" tool (Minozzi, 2022) The domains evaluated included:

- Randomization process.
- Deviations from intended interventions.
- Missing outcome data.
- Measurement of outcomes.
- Selection of reported results.
- The trials were categorized into those with low risk, some concerns, or high risk of bias.

Limitations

The potential limitations include:

- Variations in rehabilitation protocols across trials participating in the heterogeneity.

- Variability of periods of follow-up may influence long-term outcomes.
- Possible publication bias owing to the inclusion of peer-reviewed articles only.

Results

Table 1 displays the characteristics of the trials.

Population and Demographics

The sample sizes differed potentially, ranging from 18 (Ben Anguish, 2018) to 70 (David Cruz-Diaz, 2015). This reflects differences in designs and statistical power estimations.

Interventions and Treatment Limb

The included studies examine a variety of rehabilitation interventions, ranging from strength-based approaches (resistance training, hip strengthening) to balance and neuromuscular training (wobble board, vibration training, balance training with STARS).

Many trials focus on balance training, such as Haifang Wang (2021), Christopher J. Burcal (2016), and David Cruz-Diaz (2015), indicating a strong assurance on proprioceptive and neuromuscular control for recovery.

Strength-based approach, including hip strengthening (Brent I. Smith, 2017) and resistance-band (Emily A. Hall, 2015), describes the role of activating targeted muscles in restoring stability.

Post-operative interventions reported by Adam VanZile (2022) after ACL reconstruction included athletes recovering from surgery, and distinguished them from rehabilitation for chronic ankle instability.

Most interventions focus on the involved limb, specifically targeting the injured ankle, knee, or lower extremity, with one study (Ross Cloak, 2010) focusing on whole-body vibration therapy (WBVT) for unilateral ankle instability.

Dosage and Duration of Interventions

Twice-daily sessions for 5 days/week suggest a more intensive approach (Haifang Wang, 2021), whereas others (e.g., Shelley W. Linens, 2016; Ross Cloak, 2010) focus on progressive training loads over fewer sessions. Various timelines also indicate considerable variations in recovery time across varied injuries and training modalities.

Comparison of categories and Designs

Some trials compared varied training modalities (e.g., Haifang Wang, 2021; Ben Anguish, 2018), others compared rehabilitation interventions against controls (e.g., David Cruz-Diaz, 2015; Ross Cloak, 2010). This helps establish the baseline recovery impacts due to the presence of controls, revealing the relative effectiveness of the interventions.

Outcome Measures and Follow-Up Durations

The primary outcomes assessed include dynamic balance tests (Y-Balance Test, SEBT), functional performance measures (Hop Tests, FAOS, FAAM), and strength metrics (Isometric Strength, Hip Abduction).

Balance and functional performance outcomes are consistently evaluated across studies, supporting their validity in sports rehabilitation research.

Follow-up durations vary from short-term (4 weeks) to mid-term (up to 11 months post-rehabilitation in ACL recovery, Adam VanZile, 2022), reflect differences in how long outcomes are monitored.

Table 2 displays the summary of rehabilitation outcomes of the enrolled trials. Improvements have been found regarding performance, strength, balance, and dynamic stability after the implementation of different interventions. The results provide critical insights into the effectiveness of different training modalities, including balance training, resistance training, hop-based rehabilitation, and neuromuscular exercises.

Several studies utilized the Y-Balance Test (YBT) and Star Excursion Balance Test (SEBT) as primary measures of postural control and dynamic stability.

Emily A. Hall (2015) found non-significant changes (p = 0.08) in composite YBT scores, suggesting that Resistance-Band Training (RBP) and Proprioceptive Neuromuscular Facilitation (PNF) may have limited effects on functional balance compared to other interventions. Ross Cloak (2010) found that Whole Body Vibration Training (WBVT) resulted in considerable improvement of YBT scores (P 0.015-0.047); this indicates that techniques of neuromuscular stimulation can stimulate postural stability.

Table 1. General Data of the included studies

First Author	Year of publication	Sample size	Sex	Age (y), mean± SD	Intervention type	Treatment Limb	Dosage	Comparison/ control group	Outcome measure	Follow-up duration
Adam Vanzile	2022	34	17 F 17 M	16.5±1.1	Post-operative Rehab for ACL reconstruction	ACL reconstructed knee	Variable, standard rehabilitation protocol, return-to-sport testing 5-11months post-surgery	Comparison among isolated ACL tear, meniscal repair, and partial meniscectomy groups	Y-Balance, single hop, and triple hop tests	5-11 months
Haifang Wang	2021	54	27F 27M	28.2±5.6	RT Vs BT	Recurrent lateral ankle sprain	6 weeks, twice daily, 20 min per session, 5 days per week	RT Vs. BT	Isokinetic eversion strength, Y-balance and hop tests, FAOS	6 weeks
Ben Anguish	2018	18	2F 16M	18.38±1.81	PHSB Vs. SLB	Chronic ankle instability	4 weeks, 3 times/week	PHSB Vs. SLB	FAAM-ADL, FAAM-SEBT & JPS	4 weeks
Christopher J. Burca	2017	24	7F 17M	21.3±2	BT Vs BTS	Chronic ankle instability	4 weeks, 3 times/week (20 min/ session)	BT Vs. BTS	SEBT, self-assessed disability, time-boundary	4weeks+1 week post-test+1 month follow-up
David Cruz-Diaz	2015	70	35F 35M	30.36±9.37	BT Vs. CG	Chronic ankle instability	6 weeks, 3 times/week	BT Vs. CG	SEBT, CAIT, numeric rating scale (pain)	6 weeks
Emily A . Hall	2014	39	22F 17M	19.7±2.2	RBP Vs. PNF Vs. control	Chronic ankle instability	6 weeks, 3 times/week	RBP Vs. PNF Vs. control	Y-balance, Isometric strength & functional performance tests	6 weeks
Shelley W. Linens	2016	17	14F 3M Per group	22.94±2.77	Wobble Broad Rehab	Chronic ankle instability	4 weeks, 3 times/week (5 repetitions/ session)	Rehab Vs. Control	Time-in-balance, side hop, figure-of-4 eight hop tests & SEBT	4 weeks
Ross Cloak	2010	38	38F	19±1.1	Whole Body Vibration Training	Unilateral functional ankle instability	6 weeks, progressive protocol	Whole Bod y Vibration Training Vs. Control	SEBT, static balance, peroneus longus mean power frequency	6 weeks
G.R. Melam	2018	30	30 Male	21±2.2	Elastic tubing BT	Chronic ankle instability	4 weeks, 4 times/week	Elastic tubing BT Vs. Control	SEBT & single leg hop test	4 weeks
Brent I. Smith	2018	26	14F 12M	20.9±1.5	Hip Strengthening with Resistance Bands	Chronic ankle instability	4 weeks, 3 times/week	Hip strengthening Vs. Control	SEBT, balance error scoring system, hip strength (Abduction, External, Rotation), FAAM-Sport	4 weeks

F; Female, M; Male, Rehab; Rehabilitation, ACL; Anterior cruciate ligament, RT; Resistance training, BT; Balance training, PHSB; Progressive Hop-to-Stabilization balance, SLB; Single-Limb balance, BTS; Balance training with STARS, CG; Control Group, RBP; Resistance-band training, PNF; Proprioceptive neuromuscular facilitation, FAOS; Foot and Ankle outcome score, SEBT; Star excursion balance, test, JPS; Joint position sense.

Table 2. Rehabilitation Outcome Measures

Study	Rehabilitation Outcome Measures
Adam VanZile, 2022	Single Hop Test (cm): Single Hop Test (cm): Involved limb: 19.2 cm less than uninvolved limb (p < 0.001)
Adam VanZile, 2022	Single Hop Test (cm): Triple Hop Test (cm), Involved limb: 57.5 cm less than uninvolved limb (p < 0.001)
Haifang Wang, 2021	Single Hop Test (cm): Both RT and BT improved, p < 0.05; Crossover Hop Test (cm): Significant improvement in BT group, p = 0.008; 6-m Timed Hop Test (s): Both RT and BT improved, p < 0.05; YBT -Anterior (cm): RT: Pre 43.8, Post 61.8 | BT: Pre 42.5, Post 61.3 | p = 0.270; YBT - Posteromedial (cm): RT: Pre 72.6, Post 76.7 | BT: Pre 71.6, Post 87.7 | p < 0.001; YBT - Posterolateral (cm): RT: Pre 71.2, Post 75.1 | BT: Pre 74.2, Post 83.3 | p < 0.001; YBT -Total Score: RT: Pre 71.7, Post 81.5 | BT: Pre 73.1, Post 88.9 | p = 0.002; YBT - Medial (% LL): RT: Pre 72.6, Post 76.7 | BT: Pre 71.6, Post 87.7 | p < 0.001; YBT - Anterolateral (% LL): RT: Pre 71.2, Post 75.1 | BT: Pre 74.2, Post 83.3 | p < 0.001
Emily A. Hall, 2015	YBT - Composite Score: RBP: Pre 97.4, Post 102.0 | PNF: Pre 96.9, Post 101.5 | Control: Pre 99.6, Post 99.9 | p = 0.08
Shelley W. Linens, 2016	YBT - Medial (% LL): REH: Pre 0.83, Post 0.97 | CON: Pre 0.87, Post 0.85 | p < 0.0005; Figure-of-Eight Hop Test (s): REH: Pre 19.55, Post 12.40 | CON: Pre 16.20, Post 15.18 | p = 0.018; Side Hop Test (s): REH: Pre 17.65, Post 14.10 | CON: Pre 18.27, Post 17.97 | p = 0.007; Foot Lift Test (errors): REH: Pre 5.61, Post 3.82 | CON: Pre 5.00, Post 4.61 | p = 0.041; Time-in-Balance Test (s): REH: Pre 28.81, Post 45.02 | CON: Pre 27.91, Post 32.09 | p = 0.072
Ross Cloak, 2010	YBT - Medial (% LL): WBVT: Pre 84.8, Post 92.0 | Control: Pre 82.4, Post 83.7 | p = 0.047; YBT - Anteromedial (% LL): WBVT: Pre 81.0, Post 85.0 | Control: Pre 79.1, Post 78.1 | p = 0.038; YBT - Anterolateral (% LL): WBVT: Pre 68.5, Post 79.4 | Control: Pre 70.5, Post 74.7 | p = 0.015
G.R. Melam, 2018	YBT - Medial (% LL): Pre 89.5, Post 91.6 | p < 0.01; YBT -Anteromedial (% LL): Pre 84.3, Post 86.4 | p < 0.01; Single Leg Hop Test (m): Pre 1.2, Post 1.3 | p < 0.01
Brent I. Smith, 2017	Balance Error Scoring System (errors): Training: Pre 23.9, Post 9.9 | Control: Pre 22.8, Post 21.2 | p < 0.01; Hip Abduction Strength (N): Training: Pre 360.1, Post 446.3 | Control: Pre 313.7, Post 314.7 | p < 0.01; Hip External Rotation Strength (N): Training: Pre 173.5, Post 222.1 | Control: Pre 166.6, Post 169.4 | p < 0.01; FAAM-Sport Score: Training: Pre 72.1, Post 88.0 | Control: Pre 84.6, Post 84.8 | p < 0.01

G.R. Melam (2018) revealed remarkable improvements in YBT reach distances (P<0.01); this indicates the efficiency of balance training for chronic ankle instability. These findings collectively suggest that balance training interventions lead to greater improvements in dynamic postural control compared to traditional resistance training or generalized strength programs.

Hop tests were commonly employed to assess lower limb power, coordination, and functional return-to-sport readiness.

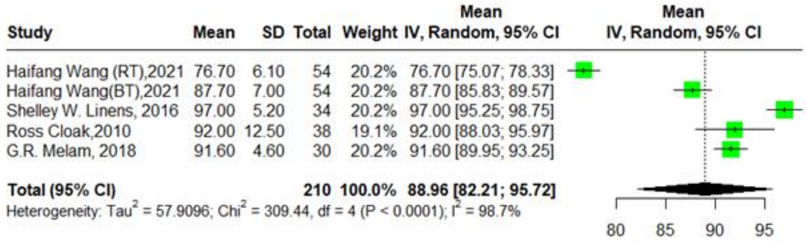
The results presented in table 2 provide strong evidence that balance training, neuromuscular activation techniques, and hop stabilization programs yield greater functional improvements than isolated strength or general rehabilitation exercises. Hop-based rehabilitation is shown to improve functional performance, jump efficiency, and return-to-sport readiness. Strength-focused training enhances neuromuscular control but may need to be combined with dynamic exercises for optimal benefits.

Meta-analysis for the Rehabilitation outcome measures

Medial Reach (Y-Balance Test)

A substantial pooled mean improvement of 88.96 (95% CI: 82.21–95.72) across five studies was found. The individual study means ranged from 76.70 (Haifang Wang, RT, 2021) to 97.00 (Shelley W. Linens, 2016). There was a very high I^2 of 98.7% (p<0.0001); this high heterogeneity could stem from differences in rehabilitation protocols, participant demographics, or baseline functional deficits. The Tau^2 value of 57.9096 further indicates substantial variance among trials. Despite this variability, the overall findings strongly support the effectiveness of neuromuscular training, balance interventions, and progressive proprioceptive exercises in enhancing medial reach distance. Figure (1)

Figure 1. Forest plot for the Medial Reach (Y-Balance Test)



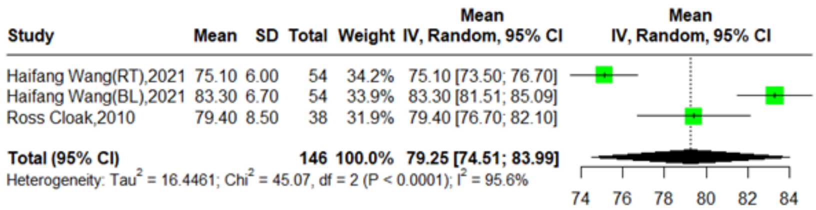
Anterolateral Y balance test

Anterolateral Reach

A pooled mean improvement of 79.25 (95% CI: 74.51–83.99) was discovered. Individual study means ranged from 75.10 (Haifang Wang, RT, 2021) to 83.30 (Haifang Wang, BT, 2021), with balance training showing greater reach gains than resistance training.

The heterogeneity was also high (I^2 = 95.6%, $p < 0.0001$), indicating substantial variation among study results. The Tau^2 value of 16.4461 further suggests that intervention effects differ significantly across the studies. Possible contributors to this heterogeneity include differences in training frequency, duration, and participant compliance. While all included studies showed improvements in anterolateral reach performance, those implementing dynamic stabilization and neuromuscular control exercises appeared to yield greater functional gains. Figure (2)

Figure 2. Forest plot for the Anterolateral Reach (Y-Balance Test)



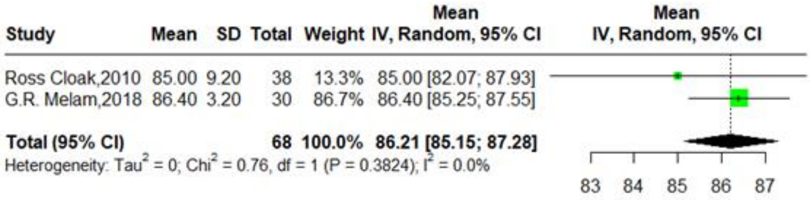
Anteromedial Y balance test

Anteromedial Reach

A pooled mean of 86.21 (95% CI: 85.15–87.28), combining data from two studies, was found. The individual study means were relatively close (85.00 in Ross Cloak, 2010, and 86.40 in G.R. Melam, 2018), indicating improvements across trials. The heterogeneity was low (I^2 = 0.0%, p = 0.3824). The Tau^2 value of 0 confirms that the variance between studies is negligible. The consistent post-rehabilitation improvements highlight the robustness of multi-planar stability exercises in restoring lower limb function. Figure (3)

The pooled analysis across medial, anterolateral, and anteromedial reach directions suggests that interventions considerably improve Y-Balance Test (YBT) performance, enhancing dynamic stability and lower limb postural control. While the anteromedial analysis showed high consistency (I^2 = 0.0%), the medial (I^2 = 98.7%) and anterolateral (I^2 = 95.6%) analyses displayed substantial heterogeneity, indicating variations in intervention effects across studies.

Figure 3. Forest plot for the Anteromedial Reach (Y-Balance Test)



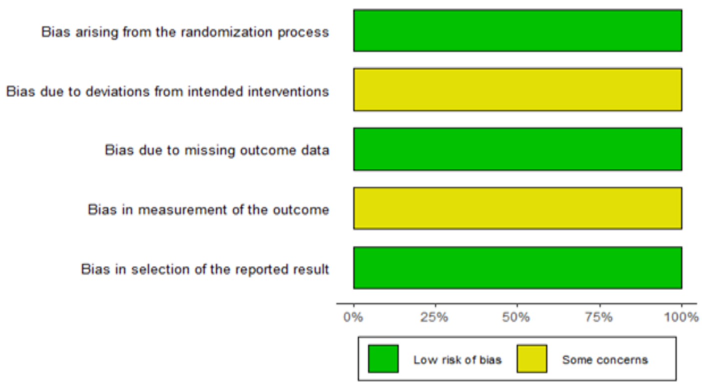
Risk of Bias (ROB) Assessment

The overall bias rating for all studies fell under the "Some Concerns" category, highlighting areas where study methodologies could be strengthened while still supporting the reliability of the reported findings (Table 3 & Fig. 4).

Table 3. Risk of bias of studies:

First Author	Bias due to Randomization	Bias due to Deviations	Bias due to Missing Data	Bias in Outcome Measurement	Bias in Selection of Reported Results	Overall Bias
Emily A. Hall	Low	Some Concerns	Low	Some Concerns	Low	Some Concerns
Ben Anguish	Low	Some Concerns	Low	Some Concerns	Low	Some Concerns
Christopher J. Burcal	Low	Some Concerns	Low	Some Concerns	Low	Some Concerns
David Cruz-Diaz	Low	Some Concerns	Low	Some Concerns	Low	Some Concerns
Ross Cloak	Low	Some Concerns	Low	Some Concerns	Low	Some Concerns
Haifang Wang	Low	Some Concerns	Low	Some Concerns	Low	Some Concerns
Adam Vanzile	Low	Some Concerns	Low	Some Concerns	Low	Some Concerns
G.R. Melam	Low	Some Concerns	Low	Some Concerns	Low	Some Concerns
Brent I. Smith	Low	Some Concerns	Low	Some Concerns	Low	Some Concerns
Shelley W. Linens	Low	Some Concerns	Low	Some Concerns	Low	Some Concerns

Figure 4. Risk of bias



Discussion

Athletes often face sports injuries that can restrict their physical abilities and reduce their competitive edge (Rojas-Valverde et al, 2025). LLIs, including ankle sprains, anterior cruciate ligament (ACL) tears, and chronic ankle instability (CAI), are among the most prevalent sports-related musculoskeletal conditions (Al Adal et al., 2019). Effective rehabilitation has a potential role in ensuring optimal and safe return to play while reducing the risk of re-injury (Kaur et al, 2025). A comprehensive analysis reported that rehabilitation interventions helped injured athletes return to sport more fully and faster (Yadav et al, 2024). Therefore, this analysis aimed to identify the most effective rehabilitation strategies for optimizing recovery and reducing re-injury risk for common sports injuries, with a primary focus on lower limb conditions reported in RCTs.

It was reported that injuries of the lower limb of varied origins account for almost 13.1% of all injuries (Smelov et al, 2021). Ankle injuries represent the second most frequent group of injury following knee injuries in sports (Fong et al, 2007). A history of ankle injury is linked with elevated risk of osteoarthritis progression, low physical activity, and joint instability (Gribble et al, 2016). Ankle sprain isn't a one-time injury, and a common sequel is the progression of chronic ankle instability, which is characterized by recurrent sprains or repetitive giving away of the ankle or both (Gribble et al, 2013). In the current analysis, we focused on LLIs, and nine of ten studies focused on ankle injuries, whereas one study focused on ACL injury.

There are several rehabilitation approaches can be implemented, including balance training which is particular for ankle and knee injuries and focus on postural control, stability, and proprioceptive feedback which may enhance neuromuscular coordination, reducing the risk of reinjury (Faghihi & Khanmohammadi, 2024), strength-based interventions which focus on restoring muscle function and improving joint stability through resistance training, hip strengthening exercises, and isometric muscle activation techniques (Monsegue et al., 2024). Hop-based rehabilitation is an exercise often applied to assess functional recovery and return to sport readiness by evaluating lower limb power, coordination, and symmetry between injured and uninjured limbs (Hamilton et al., 2008).

Neuromuscular and balance modalities can address chronic ankle instability effectively, hence reducing the risk of recurrent ankle sprains (Mollà-Casanova et al, 2021). In the current analysis, we found that neuromuscular stimulation modalities could enhance postural stability. Further analysis revealed that neuromuscular and balance training interventions were effective in enhancing medial reach distance, which is a key component of postural stability and lower limb function in injury rehabilitation.

Balance training is the main element of rehabilitation programs, and it has been widely implemented for patients with chronic ankle instability (McKeon & Hertel, 2008). Balance training has displayed potential benefits for the improvement of controlling posture and reducing the repetitive injury rates of athletes with chronic ankle instability (Park et al, 2024). Balance training can enhance the recovery of motor perception by triggering the receptors of the ankle ligaments and joint capsule, increasing the input of motor sensation, and activating gamma motor neurons (Burcal et al, 2019).

It was demonstrated that balance training is an effective modality for improving ankle stability and reducing ankle injuries (Al Attar et al, 2022). In the current analysis, we could deduce that balance training interventions lead to greater improvements in dynamic postural control compared to traditional resistance training or generalized strength programs. In a meta-analysis, it was emphasized that balance training reduced ankle sprain across several sports (RR 0.62) and also improved postural sway, joint position sense, and dynamic neuromuscular control (de Vasconcelos et al., 2018). Another systematic review revealed that balance training was an effective tool for improving postural control (Brachman et al, 2017).

In a previous systematic review that assessed the impact of neuromuscular training interventions on injury incidence, the pooled results of multi-interventions that included balance training displayed reductions in LLIs by 39% and ankle sprain injuries by 50%. Furthermore, the pooled results of balance training alone revealed a reduction in the riskof ankle sprain injuries (RR 0.64) (Hübscher et al, 2010).

Training programs that involve hop stabilization enhance postural control and function among subjects with chronic ankle instability (McKeon et al, 2008). One study compared hop and balancing training for chronic ankle instability and revealed that both interventions exhibited potential improvements; however, hop training resulted in considerably greater enhancements in dynamic performance (Park et al, 2025). In the current analysis, we found that hip-focused training was important for ankle and knee rehabilitation, and this supports its inclusion in injury prevention programs. A recent analysis included nine articles that revealed the pooled results of injury prevention programs, including balance training among 4959 soccer players, revealed a 36% reduction in ankle injury per 1000 hours of exposure. It was deduced that balance training alone or as a part of an injury prevention program reduced the risk of ankle injuries (Al Attar et al, 2022). Also, we discovered that balance training emerged as one of the most effective rehabilitation strategies, with multiple studies reporting substantial improvements in dynamic stability measures.

Effective rehabilitation is a considerable element in emphasizing optimal and safe return to play with a reduction in the risk of re-injury. Nonetheless, conventional rehabilitation interventions often focused on physiotherapy alone, and they are no longer sufficient to meet the complex requirements of today's athletes (Kaur et al, 2025). Therefore, rehabilitation has progressed toward multi-model approaches; physiotherapy focuses on regaining mobility, strength, and neuromuscular control (Kaur et al, 2025).

In the current analysis, the findings indicated that there were improvements in balance, functional performance, strength, and dynamic stability following various rehabilitation interventions. Balance training, neuromuscular activation techniques, and hop stabilization programs yield greater functional improvements than isolated strength or general rehabilitation exercises. Additionally, each rehabilitation intervention displayed effectiveness regarding specific aspects, where we found that the pooled mean of improvements ranged between 88.96 and 97, indicating variability in outcomes of the patients based on the intervention type; balance training enhanced YBT and SEBT outcomes, leading to improved postural control and injury resilience.

Hop-based rehabilitation was found to improve functional performance, jump efficiency, and return-to-sport readiness. Strength-focused training enhanced neuromuscular control but may need to be combined with dynamic exercises for optimal benefits, indicating that multi-modal rehabilitation may be more effective compared to a single intervention, as multi-modal rehabilitation would integrate strength, proprioception, and functional performance tasks, which are more effective in enhancing recovery and reducing re-injury risk in athletes with LLIs. However, this requires further investigation. Future studies should focus on long-term outcomes and standardized rehabilitation protocols to further enhance sports injury management.

This analysis included some limitations; there was potential heterogeneity in the included articles which revealed variability in duration, adherence and intensity of the interventions which made it hard to determine the best intervention. Also, the included studies reported the outcomes of patients at short-term and there is no data on the long-term outcomes of the patients. Therefore, future studies should focus on long-term outcomes and standardized rehabilitation protocols to further enhance sports injury management.

Conclusions

The effectiveness of rehabilitation programs for common sports injuries is well-supported by empirical evidence, with balance training, hop stabilization exercises, and strength-based rehabilitation emerging as the most effective interventions. Balance training enhances dynamic stability, hop-based interventions improve functional performance, and strength-focused strategies contribute to neuromuscular control. While high heterogeneity exists across studies, the overall findings reinforce the importance of multi-modal rehabilitation approaches in optimizing recovery and reducing the risk of reinjury in athletes.

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