



(SK) Vplyv tréningu rovnováhy na nestabilitu členkového kĺbu u športovcov: systematický prehľad randomizovaných kontrolovaných štúdií

Effect of Balance Training on Ankle Instability in Athletes: A Systematic Review of Randomized Controlled Trials

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SUMMARY/ABSTRACT

Background: Chronic ankle instability (CAI) is one of the most prevalent sports injuries among athletes and is defined by recurrent ankle sprains, episodes of giving way, poor proprioception, and postural control deficits. Balance training is a common rehabilitation technique, but there is no clear evidence about the effectiveness of various balance training techniques.

Objectives: The purpose of this study was to systematically review randomized controlled trials (RCTs) that examined the effects of balance training on ankle instability, postural control and functional performance in athletes with CAI.

Method: The search was done in six online sources, including Google Scholar, PubMed, PEDro, Cochrane Library, Web of Sciences, and Scopus and the words "balance training," "ankle instability," "balance interventions," and "athletes" were used in the search and patients in the studies were only chosen at random and had to have been identified with CAI using standard clinical criteria and valid tools, such as the Cumberland Ankle Instability Tool (CAIT) and the Foot and Ankle Ability Measure (FAAM) was the patient reported outcome measure and it was used to find out how well the patient could do things, but it was not used as a medical tool and we got rid of the studies that had people with acute ankle sprains, non-athletic groups, or treatments and the Physiotherapy Evidence Database (PEDro) scale was used to rate the study method quality.

Results: Fifteen randomized controlled studies with 561 athletes aged 18–45 years met the inclusion criteria. Of these, 281 participants were treated with balance-based therapies and 280 with alternative rehabilitation programmes or control interventions. Methodological quality of the included studies, according to the PEDro scale, was rated as moderate-to-high (5-8). In general, balance-based therapies were related with improvements in dynamic balance, postural control and self-reported ankle function across studies. The most common tests associated with positive changes in outcomes were the SEBT, Y-Balance Test, CAIT, FAAM and FADI. Furthermore, several studies have shown enhancement in proprioception, neuromuscular control, reaction time and movement coordination.

Conclusion: The results of this review suggest that balance-based rehabilitation may be beneficial in improving dynamic balance, postural control and self-reported ankle function in athletes with chronic ankle instability. However, significant variety in participant characteristics, intervention protocols, outcome measures, and follow-up duration prohibits direct comparison between research, and precludes conclusive findings regarding the most successful intervention technique. More high quality randomized controlled trials with standardized outcome measures and longer follow-up periods are needed to better understand the long-term effectiveness of balance-based therapy.

KEYWORDS

Chronic ankle instability, balance training, athletes, postural control, randomized controlled trial, neuromuscular rehabilitation, Cumberland Ankle Instability Tool (CAIT), Star Excursion Balance Test (SEBT).

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1 INTRODUCTION

When it comes to human locomotion and athletics, the ankle joint is crucial and it provides the necessary stability and movement for activities like walking, running, cutting movements, and tasks that involve balance and the two main joints are the ankle and the subtalar complex, which is situated inside the talus and the calcaneus ¹, and the ankle is prone to damage, particularly sprains, which account for fifteen to thirty percent of all sports related injuries, since it is the most functionally used joint in sports and among the most prevalent types of sports injuries, ankle sprains account for ² and it accounts for a significant amount of time loss injuries in both contact and no- contact sports, and it is among the most common musculoskeletal ailments seen in athletes and despite its perceived insignificance, lateral ankle spraining is one of the most common injuries in athletes or sports participators may experience long lasting symptoms and problems, and there a good chance it will come back and on the other hand, chronic ankle instability (CAI) can develop from frequent ankle sprains and ankle sprains, aches, swelling, and impaired performance in sports and daily life are other common symptoms of this condition^{3,4}.

In 2014, the International Ankle Consortium (IAC) came up with the diagnostic guidelines to get eradicate of these differences in how CAI is diagnosed and in the past, they have had a major lateral ankle sprain, many sprains, given away, and used a self-reported verified assessment and even though there have been a lot of studies on how common ankle sprains are in sports, most of them show that the CAI is based on self-reported scales and does not look at a lot of the patient medical background, which could make the diagnosis less accurate ⁵.

Functional and mechanical components both contribute to CAI multifaceted nature and lax ligaments and altered joint kinematics are the causes of mechanical instability, which affects the joints ⁴; dysfunctional proprioception, neuromuscular control, muscle strength, postural stability, and sensorimotor integration all contribute to functional instability, and athletic performance, balance control, and dynamic mobility can all be negatively impacted by these limitations ⁶, which can lead to further ankle injuries and degenerative disorders like post traumatic osteoarthritis and in addition, recent research has connected CAI to changes in how the central nervous system processes information, which in turn impairs postural control and motor activity planning while doing athletic tasks 3,7,8.

Athletes whose ankles are chronically unstable often have weak muscles in the areas around their ankle bones and this is because the dorsiflexor, plantarflexor, evertor, and invertor muscles lose their strength, which is needed to move the ankle, both in a static position and during sports^{9,10} and therefore, the rehabilitation programme of people with ankle instability includes strength training.

Patients with CAI have shown improvements in muscle performance, joint stability, and associated functional outcomes after engaging in ankle strengthening activities with resistance ^{8,11,12}. Additional evidence from recent research points to the role of psychological variables, such as kinesiophobia, in determining movement pattern and reinjury risk and strength and balance training exercise therapies have a significant impact on both the mental and physical health of athletes who have ankle instability ^{13,14}.

The number of players who have CAI is very high and cross sectional studies have found rates of 30 to more than 70 percent across a wide range of sports, based on the sport, the level of competition, and the diagnostic factors used ^{5,15} and new research on professional and teen athletes has shown that female athletes and athletes who do acrobatic or high impact sports are more likely to develop CAI ^{5,16} and these data show that CAI has a big effect on how well athletes do, how often injuries happen, and how long their careers last.

The majority of ankle injuries, at 78%, are lateral ligament sprains and casual gamers who play for enjoyment, fitness, or less serious competition are just as likely as professional or elite athletes to have these types of injuries and the majority of instances are treated conservatively, but a small percentage of

individuals may develop CAI, characterised by persistent discomfort and instability during physical exercise or while carrying out routine daily tasks 16,17.

Individuals with CAI lose control of their posture and their ability to balance and there is evidence in the literature that CAI athletes have problems with their static and dynamic balance³, as well as their ability to sense joint position and react to changes during sports specific activities and these problems are caused by a delay in the activation of peroneal muscles⁷ and these sensory problems make it harder to keep your lower limbs stable and change the way you walk and this changes the way loads are distributed around your ankle joint, making players more likely to get hurt again and again^{9,18}.

Because of this, balancing training is now considered an essential part of the rehabilitation process for patients with CAI and a well-rounded program for balance training will include many aspects such as unstable surface training, task specific functional challenges, perturbation based exercise, and single limb stance and these elements work together to improve postural stability, neuromuscular control, and proprioception and research has demonstrated that patients with CAI can greatly benefit from balance training as a kind of therapy and it improves their postural control and dynamic balance, as well as their self-reported ankle stability and functional performance^{9,17,18} and in addition, there is evidence that balance based therapies can improve athletic performance and decrease the incidence of ankle sprains^{1,6} and although there has been a lot of study on the subject recently, it is still difficult to draw firm conclusions on the efficacy of balance training for CAI patients due to the wide variety of intervention methodologies, outcome measures, and participant characteristics and so, to improve athlete ankle instability, postural control, and functional performance, this systematic review will synthesise the data from randomised controlled trials that address the impact of balance based therapies. Therefore, this systematic review aimed to evaluate the effectiveness of balance training on ankle instability, balance performance and functional outcomes in athletes with ankle instability.

2 METHODS

This was prospectively registered in the PROSPERO Database (Regn. no: CRD420251142013) on 17 November 2025, before the commencement of the review procedure and the implementation of the study was based on the PRISMA 2020 guidelines¹⁹ in order to secure transparency and completeness of reports.

2.1 SEARCH STRATEGY

Google Scholar, Cochrane Library, PEDro, PubMed, Scopus Database, and Web of Science were rigorously searched to discover RCTs evaluating the effects of balance training on ankle instability in athletes with other therapies or no intervention at all and from December 2025 until February 2026, the search was carried out.

The following phrases were used in the search: athletes, balance interventions, ankle instability (either temporary or chronic), and balance training and in addition, the MeSH phrase "ankle instability" was also input, and the final search was conducted using the AND and OR Boolean operators.

In the supplementary materials, you may find each database specific search methodology laid out in Table 1 and the most recent search took place in February of 2026 and Google Scholar top 100 results were culled based on their relevance and in addition, any more relevant publications were located by reviewing the reference lists of the research that were utilised.

There were three stages to selecting the study: first, finding relevant articles using the keywords; second, reviewing the titles and abstracts of those articles; and finally, reading the complete texts of those articles.

2.2 STUDY SELECTION

The studies were qualified if they met the standards that had already been set and randomised controlled studies on both male and female players were the only ones that were looked at in this review and following the rules set by the IAC ³, the people who took part had to have been identified with an unstable ankle condition like CAI and in particular, the subjects had to say that they had at least one big ankle sprain in the past year and that they often feel like their ankles are giving way or are unstable and these factors were also backed by validated self-reported outcome measures, such as the CAIT or the FAAM.

Research that used definitions of functional ankle instability (FAI) before those listed above was also accepted. Although chronic ankle instability (CAI) and functional ankle instability (FAI) are distinct terms, they share several features, including a history of ankle sprain, recurrent episodes of the ankle giving way, and ongoing feelings of instability or reduced ankle function. Therefore, studies that used either CAI or FAI were included in this review, provided that the participants demonstrated similar clinical characteristics and met criteria comparable to those recommended by the International Ankle Consortium ³.

As long as it had the same clinical appearance (for example, a history of injury and recurring instability) and when research did not have a clear or uniform definition of ankle instability, eligibility was based on checking that these important traits were present, and any changes from this were carefully looked at during the data synthesis process.

The study looked at studies that looked at interventions for balance training, either by themselves or with strength training, and also, we only looked at English language stories and the studies were not included if they were case reports or narrative reviews and a study was also not included if the cases included people with acute ankle sprains, people who did not play sports, or people who had surgery.

The study selection was independently performed by three reviewers to reduce the risk of bias. The titles and abstracts of all retrieved studies were first screened against pre-defined inclusion and exclusion criteria. Full-text articles of studies determined to meet the inclusion criteria were then retrieved and independently reviewed by all three reviewers to determine final study inclusion. Disputed selections during this process were settled through discussion and consensus among reviewers.

2.3 DATA SYNTHESIS

A quantitative meta-analysis was not undertaken because the included studies showed considerable variation in several aspects. Differences were observed in participant characteristics, intervention approaches, comparison groups, outcome measures, and follow-up periods. The interventions ranged from conventional balance training to hop-stabilization exercises, whole-body vibration, stroboscopic training, and combined strength-balance programmes. In addition, a variety of outcome measures, including the SEBT, Y-Balance Test, CAIT, FAAM, FADI, and IdFAI, were used across studies. Given this heterogeneity, combining the results into a single pooled estimate was considered inappropriate. Therefore, the findings were synthesized using a qualitative narrative approach to provide a comprehensive overview of the available evidence.

2.4 METHODOLOGICAL QUALITY ASSESSMENT

A meta-analysis was not conducted because substantial clinical and methodological heterogeneity existed among the included studies. Although all studies investigated balance-based interventions for chronic ankle instability, considerable variation was observed in participant characteristics, intervention protocols, comparator conditions, outcome measures, and follow-up durations.

The included interventions comprised conventional balance training, hop stabilization exercises, stroboscopic balance training, whole-body vibration training, single-limb balance programs, combined strength-and-balance interventions, and nine-square exercise programs. These interventions differed substantially in training frequency, intensity, duration, and therapeutic objectives.

Furthermore, the studies employed diverse outcome measures, including the Star Excursion Balance Test (SEBT), Y-Balance Test, Cumberland Ankle Instability Tool (CAIT), Foot and Ankle Ability Measure (FAAM), Foot and Ankle Disability Index (FADI), proprioception assessments, neuromuscular control measures, gait parameters, and sport-specific performance outcomes. Due to the lack of a consistent outcome framework and variability in reporting formats, pooling results into a single quantitative estimate would have been methodologically inappropriate and potentially misleading.

Additional heterogeneity was present in athlete populations, sporting disciplines, diagnostic criteria for chronic ankle instability, comparator interventions, and follow-up periods. Several studies also reported insufficient statistical information, including missing standard deviations, change scores, confidence intervals, or effect size data, limiting the feasibility of quantitative synthesis.

3 STARTING POINT, OBJECTIVE, TASKS

This systematic review looked at all the RCTs that have been done so far on the benefits of balance training on players with CAI ankle instability, postural control, and functional performance.

4 RESULTS

4.1 Synthesis of Included Trials

The study examined at the effect of balance training on ankle instability in fifteen studies that met the selection criteria^{8,10–14,18,20–27} and all of these articles were released between 2009 and 2025 and they were all randomised clinical studies that took place in eight different countries: the USA, Korea, Iran, China, Georgia, Spain, Thailand, Pakistan, and Turkey and there were 561 people who took part in the clinical studies that were done to find out what caused ankle stiffness and the people taking part are between the ages of 18 and 45 and out of the total group size, 281 people got balance training and the other 280 people got either other types of treatments or nothing at all.

Ten of the fifteen studies used the CAIT Questionnaire to find out if the ankle was unstable^{8,10,11,13,14,20,21,24–26} and other studies used patient reported outcome measures, such as the Functional Ankle Disability Index (FADI) and the FAAM, to find out if the ankle was unstable^{22,23,27} and in one study, the Functional Ankle Instability Questionnaire was used to find ankle instability¹² and in another study¹⁸, other gait measures were used instead of surveys to find ankle instability (Table no 2).

The Star Excursion Balance Test (SEBT) was used in most of the studies to measure dynamic balance based on performance and for one study, the HUBER Balance Device¹⁴ was used to measure balance and other than these objective tests, some studies, such as the Foot and Ankle Ability Measure Activity of Daily Living (FAAM ADL)²² used self-reported data and it is important to note, though, that these surveys do not directly test how well someone can balance; they only test how well someone thinks they can do things and this is why the result of objective balance and patient reported measures were looked at in this study in different ways.

Each study had a different balance training protocol, but most of them included a mix of static and dynamic balance training, training on unstable surfaces, single leg stance training, hop stabilization training, and neuromuscular or stroboscopic training and the control groups, on the other hand, did regular exercise programs or no balance training at all.

4.2 Methodological quality

The methodological quality of the included studies was assessed according to PEDro scale²⁸, and all fifteen studies reported using a random allocation method, and eight of those studies included specific eligibility criteria and six trials used concealed allocation, and all fifteen demonstrated baseline comparability and despite six research claiming to have used blinded assessors, not a single study mentioned patients or therapists being blinded and there was enough follow up in all fifteen investigations and using intention to treat analysis, four trials were conducted and point estimates with variability measurements and between group comparisons were both given in all investigations. The PEDro scores ranged from 5 to 8, suggesting moderate to high methodological quality. However, no study reported blinding of participants or therapists, and only a minority of studies reported concealment of allocation or intention-to-treat analysis. Hence, the methodological quality of the included research should be assessed with caution.

4.3 Measurement Tools and Reported Outcomes

The major results that were looked at in the studies that were included were functional performance, postural control, and ankle instability and an important way to check dynamic balance was with the SEBT^{8,10-14,18,20-27}, and the Cumberland Ankle Instability Tool (CAIT) and the FAAM Sport questionnaires^{8,10,11,13,14,20-27} were used to measure functional ability and ankle instability and the surveys were self-reported and a questionnaire called the Identification of Functional Ankle Instability Questionnaire (IdFAI) was used in one study to correctly find people who had CAI¹². Also, not many studies looked at the neuromuscular and physical results, like how the body moves, how fast it reacts, how muscles are activated, how strong the ankles are, and how active the cortex is.^{13,14}

4.4 Impact of Balance-Based Interventions on Ankle Stability

a) Dynamic Balance and Postural Stability

Fourteen out of fifteen studies found that participant balance significantly improved following the training intervention, and in general, and in a specific reach direction (i.e., anterior, posteromedial, and posterolateral), significant improvements were noted when utilising the Y balance test to measure the dynamic balance^{8,12,13,18,24}.

With the exception of a single trial that used the HUBER Balance gadget¹⁴, the balance training groups outperformed the control and strength only groups in nearly all trials, and less postural sway and greater single leg stability were outcomes of unstable surface and progressive balance challenge dynamic balance programs^{20,26}. These outcomes demonstrate that CAI athlete postural control improved following balance training.

b) Self-Reported Ankle Function and Instability

Fourteen studies looked at what patients said about their results using tools like the Visual Analogue Scale (VAS) for subjective instability, FAAM (ADL and Sport), and CAIT and researchers found that balance training made people feel more confident in their abilities and improved their ability to play sports^{8,12,13,18,26}.

Several studies showed that muscle and physiological changes that were good happened after balance training and proprioception, the ability to feel where the ankle joint is, response time, muscle activation patterns, and movement coordination were all found to be better^{14,20,27} and stroboscopic and sensorimotor

balance training methods show extra benefits in cortical activity and muscle efficiency and this suggests that changes in the central nervous system are helping to make the ankle more stable. ¹³ said that teen players who did both strength and balance training had better neuromuscular control and functional efficiency.

c) Between-Group Comparison

Studies on the effects of strength training on isolated muscle strength and balance training on dynamic balance and postural control found that both interventions improved ankle functioning ²⁷ and however, combined strength and balance programs were determined to be the most effective in terms of balance, function, and patient reported outcome ^{21,22} and these findings suggest that, in comparison to CAI, balance training may be more effective in reducing ankle instability and enhancing functional outcomes.

5. Discussion

There were fifteen RCTs included in this study and the purpose was to find out how balance training routines affected athletes with CAI who had unstable ankles and the results mostly point to the idea that balance based therapy is connected to changes in positional control, dynamic stability, and how well athletes say their ankles work and having said that, the studies that were included were very different in how the treatments were set up, who took part, what they looked at, and how long they lasted and this lack of regularity makes it harder to directly compare results and suggest one type of training over another based on how well it works.

One of the most common effects across all the studies that were looked at was an improvement in dynamic balance, especially as measured by the SEBT.¹¹, for instance, found that people who did balance training for 6 weeks had big improvements in their reach in several directions, which could mean that they were better able to control themselves during moving tasks and for example, in an observational study, ²⁵ it was shown that teenage athletes still showed significant improvements in SEBT ability after only four weeks and ten rounds of a shorter version of the SEBT intervention. ²⁶ people who used a nine-square workout program got better and all of these results support the idea that the balance training program is a good way to get back to normal levels of proprioception and muscle coordination, both of which are important for keeping your ankle stable during sports and this fits with what¹⁸, had found before; they said that coordinated action got better after balance changes.

Along with changes in ability, some studies found that player ideas about how their ankles worked changed and in the end, people who took part in therapy said they felt more stable and confident after doing exercises like the FAAM, FADI, and CAIT and as an example, ¹² found that individual who did both power training and balance training felt more useful and stable and since there is not a clear difference between the groups, it is possible that these effects are not just due to balance training but to changes that happen during recovery in general and even the studies that mixed strengthening and balance workouts found that the combination worked, suggesting that a more combined focus might be useful.

Nevertheless, there is a lack of sufficient information to determine its practical value in therapeutic contexts and balance training has just begun to explore the possibility of including dynamic and sport specific elements and particularly for an athletic demographic, preliminary data from²⁰ suggests that hop stabilization exercises increase landing control measures and decrease felt instability and the variations across methods were minimal, though, when put side by side with conventional balance training and both treatments resulted in improvements, as reported ^{23,25}; however, the latter study only included a limited sample of female basketball players in their analysis, which may restrict the generalisability of the results.

Recent research has looked at alternative or supplementary methods to enhance training results and examples of such studies are , ⁸ and ²¹ which investigated the use of whole body vibration (WBV) to supplement balance training; the results showed enhanced ankle function and balance and since the differences

between WBV and regular balance training were not immediately apparent, one may wonder if WBV enhances the benefits of balance training or if it acts as a standalone intervention and stroboscopic training, which alters brain activity by influencing the visual system, has shown promising effects and there is a lack of data and uncertainty regarding its application in clinical practice and psychological aspects are among the other areas that start to get some attention as well and athlete performance, stability, and kinesiophobia (a fear of movement) were all shown to increase with strength and balance training, according to study ¹³ and an athlete mobility upon return to sport might be affected by fear of re injury, leading to extended absences from competitive play and therefore, it is not enough to focus on physical deficits in order to achieve successful rehabilitation; psychological impediments must also be addressed.

Previous study by ¹⁸ also showed that training your balance can change the way you walk by improving your rhythm and the regularity of your movements and even though the people in this study were not athletes, it is still a good idea to think about how balance training might help with more than just simple balance skills.

The main finding of this study is that balance training programs usually make both performance based and self-reported measures better but the size of these kinds of gains is not always clear, and they are usually pretty small and more importantly, balance training by itself does not always work better than other rehabilitation methods and this means that the improvements seen are likely due to changes in the muscles and nerves that happen with most rehabilitation methods, not just one type of exercise.

There are several limitations to be taken into account when interpreting the results of this review. A significant amount of study heterogeneity was noted in terms of study participant characteristics, age, sex, sport discipline, intervention type, training duration, training frequency, outcome measures, and followup periods for the studies included. Comparisons between studies were further restricted by the use of different diagnostic criteria for ankle instability and the different types of assessment tools used. Additionally, most of the studies assessed only short-term outcomes, thus it was hard to assess whether the improvements reported persisted over time. However, a quantitative meta-analysis was not performed, making it impossible to calculate pooled effect sizes and to give an estimate of the overall size of treatment effects from the studies. These results, along with clinical data, show that balance training is a significant part of recovering CAI athletes and when it is done, it should not be done by itself but along with some kind of power training or sport specific exercise and multidirectional and useful programs will be very helpful for players who are just starting to play sports again.

Most of the studies require larger sample sizes and more prolonged follow-up period to draw robust conclusions that would enhance their clinical applicability.

Overall, it looks like balance training is a solution that works because it improves both player balance and how they think their ankles work (perceived ankle performance) compared to people who have CAI but as of right now, there has not been a study that proves for sure which type of training method might be the best and as part of future study, standardised ways to training methods could be created and there could also be larger sample sizes and more prolong follow up periods to help clinician more.

6. Conclusion

The current systematic review indicates that balance rehabilitation is associated with enhanced dynamic balance, postural control and self-reported ankle function in athletes with chronic ankle instability. There were also several studies reporting beneficial effects on proprioception, neuromuscular control, and functional performance. There are also significant differences in the characteristics of the participants, intervention techniques, outcome measures, and follow-up time between studies, which prevent direct comparison between them and a definitive conclusion about the best type of balance training. Thus, although balance training seems to be crucial in the rehabilitation of athletes with chronic ankle instability, additional high-

quality RCTs with longer follow-up periods and standardized outcome measures are needed to identify the most effective type, frequency, duration and long-term outcomes of balance-based interventions.

5 ZUSAMMENFASSUNG

Hintergrund: Chronische Sprunggelenkinstabilität (chronic ankle instability, CAI) gehört zu den häufigsten sportbedingten Verletzungsfolgen bei Athletinnen und Athleten und ist durch wiederkehrende Distorsionen des Sprunggelenks, Episoden des Wegknickens („giving way“), eine beeinträchtigte Propriozeption sowie Defizite der posturalen Kontrolle gekennzeichnet. Gleichgewichtstraining ist eine häufig eingesetzte rehabilitative Maßnahme; hinsichtlich der Wirksamkeit unterschiedlicher Formen des Gleichgewichtstrainings besteht jedoch bislang keine eindeutige Evidenz.

Zielsetzung: Ziel dieser Studie war es, randomisierte kontrollierte Studien (RCTs), in denen die Auswirkungen von Gleichgewichtstraining auf Sprunggelenkinstabilität, posturale Kontrolle und funktionelle Leistungsfähigkeit bei Athletinnen und Athleten mit CAI untersucht wurden, systematisch auszuwerten.

Methode: Die Literaturrecherche wurde in sechs elektronischen Datenquellen durchgeführt: Google Scholar, PubMed, PEDro, Cochrane Library, Web of Science und Scopus. Für die Suche wurden die Begriffe „balance training“, „ankle instability“, „balance interventions“ und „athletes“ verwendet. Eingeschlossen wurden ausschließlich randomisierte Studien mit Teilnehmenden, bei denen eine CAI anhand standardisierter klinischer Kriterien und validierter Instrumente diagnostiziert worden war. Hierzu gehörten unter anderem das Cumberland Ankle Instability Tool (CAIT) sowie die Foot and Ankle Ability Measure (FAAM). Die FAAM wurde als patientenberichtetes Outcome-Instrument zur Beurteilung der funktionellen Leistungsfähigkeit verwendet, nicht jedoch als diagnostisches Instrument. Studien mit Personen mit akuten Sprunggelenksdistorsionen, nicht sportlich aktiven Populationen oder nicht relevanten Behandlungsansätzen wurden ausgeschlossen. Die methodische Qualität der eingeschlossenen Studien wurde anhand der Skala der Physiotherapy Evidence Database (PEDro) bewertet.

Ergebnisse: Fünfzehn randomisierte kontrollierte Studien mit insgesamt 561 Athletinnen und Athleten im Alter von 18 bis 45 Jahren erfüllten die Einschlusskriterien. Davon erhielten 281 Teilnehmende gleichgewichtsbasierte Interventionen und 280 alternative Rehabilitationsprogramme oder Kontrollinterventionen. Die methodische Qualität der eingeschlossenen Studien wurde anhand der PEDro-Skala als mittel bis hoch eingestuft (5–8 Punkte). Insgesamt waren gleichgewichtsbasierte Interventionen in den untersuchten Studien mit Verbesserungen des dynamischen Gleichgewichts, der posturalen Kontrolle und der selbstberichteten Sprunggelenkfunktion verbunden. Zu den am häufigsten verwendeten Testverfahren, bei denen positive Veränderungen festgestellt wurden, gehörten der Star Excursion Balance Test (SEBT), der Y-Balance Test, das CAIT, die FAAM und der Foot and Ankle Disability Index (FADI). Darüber hinaus zeigten mehrere Studien Verbesserungen der Propriozeption, der neuromuskulären Kontrolle, der Reaktionszeit und der Bewegungskoordination.

Schlussfolgerung: Die Ergebnisse dieser systematischen Übersichtsarbeit deuten darauf hin, dass eine gleichgewichtsbasierte Rehabilitation zur Verbesserung des dynamischen Gleichgewichts, der posturalen Kontrolle und der selbstberichteten Sprunggelenkfunktion bei Athletinnen und Athleten mit chronischer Sprunggelenkinstabilität beitragen kann. Die erhebliche Heterogenität hinsichtlich der Merkmale der Teilnehmenden, der Interventionsprotokolle, der verwendeten Outcome-Parameter und der Dauer der Nachbeobachtung erschwert jedoch direkte Vergleiche zwischen den Studien und erlaubt keine eindeutigen Schlussfolgerungen darüber, welche Interventionsform am wirksamsten ist. Weitere qualitativ hochwertige randomisierte kontrollierte Studien mit standardisierten Outcome-Maßen und längeren Nachbeobachtungszeiträumen sind erforderlich, um die langfristige Wirksamkeit gleichgewichtsbasierter Therapieansätze besser beurteilen zu können.

7 SUPPLEMENTARY

Detailed search strategy table

Database	Search Strategy
PubMed	("Ankle Instability"[Mesh] OR "chronic ankle instability" OR "functional ankle instability" OR "ankle instability") AND ("balance training" OR "balance intervention" OR "proprioceptive training" OR "neuromuscular training") AND (athlete OR athletes)
PEDro	("chronic ankle instability" OR "functional ankle instability" OR "ankle instability") AND ("balance training" OR "balance intervention" OR "proprioceptive training" OR "neuromuscular training") AND (athlete OR athletes OR sport)
Cochrane Library	("chronic ankle instability" OR "functional ankle instability" OR "ankle instability") AND ("balance training" OR "balance intervention" OR "proprioceptive training" OR "neuromuscular training") AND (athlete OR athletes OR sport)
Scopus	TITLE-ABS-KEY (("chronic ankle instability" OR "functional ankle instability" OR "ankle instability") AND ("balance training" OR "balance intervention" OR "proprioceptive training" OR "neuromuscular training") AND (athlete OR athletes OR sport))
Web of Science	TS= ("chronic ankle instability" OR "functional ankle instability" OR "ankle instability") AND ("balance training" OR "balance intervention" OR "proprioceptive training" OR "neuromuscular training") AND (athlete OR athletes OR sport)
Google Scholar	("chronic ankle instability" OR "functional ankle instability" OR "ankle instability") AND ("balance training" OR "balance intervention" OR "proprioceptive training" OR "neuromuscular training") AND (athlete OR athletes OR sport)

Note: The literature search included studies published from database inception until February 2026. Only articles published in English were considered for inclusion. For Google Scholar, results were ranked by relevance and the first 100 records were screened. To ensure that all relevant studies were identified, the reference lists of the included articles were also manually searched.

Figure 1: PRISMA flow diagram of study selection

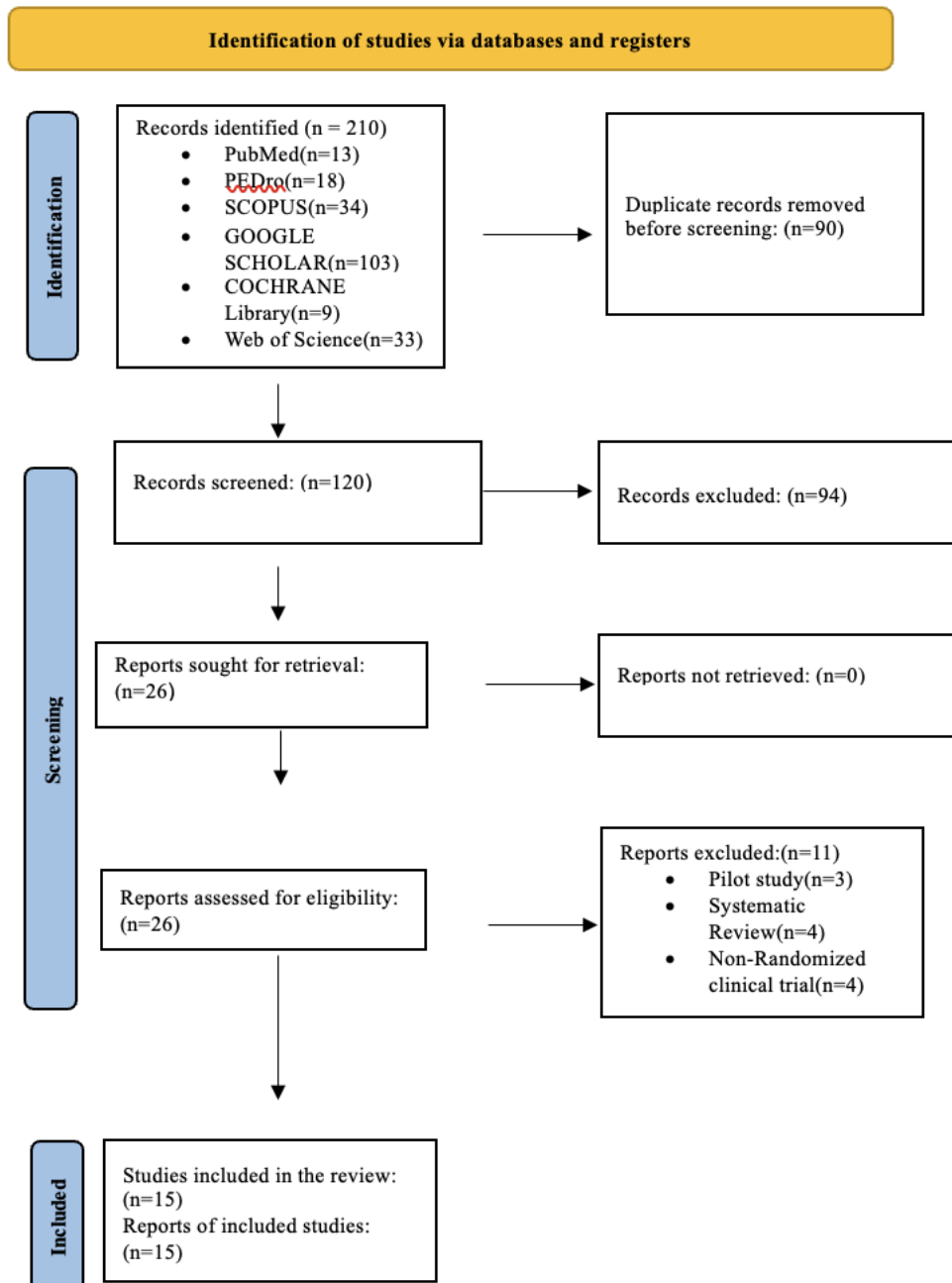


Table 1: *Assessment of Methodological Rigour Across Included Trials Using the PEDro Scale*

S.no	Study	Eligibility Criteria	Random Allocation	Concealed Allocation	Baseline Comparability	Blind Subjects	Blind Therapists	Blind Assessor	Adequate Follow-up	Intention-to-Treat Analysis	Between-Group Comparison	Point Estimates & Variability	Total
1	McKeon et al. (2009)	N	Y	Y	Y	N	N	N	Y	Y	Y	Y	7
2	Cruz-Díaz et al. (2014)	N	Y	Y	Y	N	N	Y	Y	N	Y	Y	7
3	Wright et al. (2017)	Y	Y	Y	Y	N	N	N	Y	N	Y	Y	6
4	Sierra-Guzmán et al. (2017)	Y	Y	N	Y	N	N	Y	Y	N	Y	Y	6
5	Hall et al. (2018a)	N	Y	N	Y	N	N	N	Y	N	Y	Y	5
6	Hall et al. (2018b)	N	Y	N	Y	N	N	N	Y	N	Y	Y	5
7	Ardakani & Wikström (2019)	N	Y	N	Y	N	N	Y	Y	N	Y	Y	6
8	Spencer Cain et al. (2020)	Y	Y	Y	Y	N	N	Y	Y	N	Y	Y	7
9	Chang et al. (2021)	Y	Y	N	Y	N	N	N	Y	N	Y	Y	5
10	Uzlaşır et al. (2021)	N	Y	Y	Y	N	N	N	Y	Y	Y	Y	7
11	Thanasootr et al. (2022)	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8
12	Mukhtar et al. (2023)	Y	Y	N	Y	N	N	N	Y	N	Y	Y	5
13	Yekdaneh et al. (2024)	Y	Y	N	Y	N	N	N	Y	N	Y	Y	5
14	Park et al. (2024)	Y	Y	N	Y	N	N	Y	Y	N	Y	Y	6
15	Park et al. (2025)	Y	Y	N	Y	N	N	Y	Y	N	Y	Y	6

In the PEDro scale assessment, ‘Yes’ indicates that the study met the criterion, whereas ‘No’ indicates that it did not.

Table 2: Overview of Trial Designs, Populations, and Interventions

S.no	Author	Year	Study Design	Participants	Intervention	Outcome Measures	Country
1	McKeon et al.	2009	RCT	29 Athletes with FAI	4 weeks of supervised Balance training vs. a control group (no intervention)	Gait parameters (Kinematic measure of rearfoot inversion/eversion, Shank rotation kinematic, shank-rearfoot coupling, SEBT	USA
2	Cruz-Díaz et al.	2014	RCT	70 CAI	6-week balance training Vs Usual strength training	CAIT SEBT, Pain/instability,	Spain
3	Wright et al.	2017	RCT	40 Collegiate athletes with CAI	Balance-based vs strength-based rehabilitation	CAIT, SEBT, FAAM	Georgia (USA)
4	Sierra-Guzmán et al.	2017	RCT	50 athletes with CAI	6 weeks WBV training on unstable surface Vs no intervention	SEBT / Y-Balance, CAIT	Spain
5	Hall et al.	2018a	RCT	39*Athletes with CAI	6 weeks of balance training exercise vs strength training and a mild to moderate bicycle workout	SEBT, strength testing, clinical ankle stability, IdFAI	USA
6	Hall et al.	2018b	RCT	39*Athletes with CAI	6 weeks of balance/strength training vs. a mild to moderately bicycle workout	FAAM-ADL, FAAM-Sport	USA
7	Ardakani & Wikstrom	2019	RCT	28 Collegiate athletes with CAI	6-week hop-stabilization training vs usual training	CAIT, SEBT, landing biomechanics	Iran
8	Spencer Cain et al.	2020	RCT	43 high-school athletes with CAI	4 weeks resistance-band vs single limb balance training BAPS vs no intervention	side-hop test, FAAM, SEBT, CAIT, figure-8 hop test.	Georgia (USA)
9	Chang et al.	2021	RCT	63 female athletes with CAI	6 weeks WBV + balance training vs no intervention	SEBT, isokinetic strength, CAIT	China
10	Uzlaşır et al.	2021	RCT	39 athletes with CAI	6 weeks of Stroboscopic balance training vs no intervention	CAIT, HUBER Balance Device	Turkey
11	Thanasootr et al.	2022	RCT	18 collegiate athletes with CAI	6 weeks of the Nine-square exercise program vs usual training	SEBT, CAIT, FAAM	Thailand
12	Mukhtar et al.	2023	RCT	30 basketball players with CAI	6 weeks of Hop-stabilisation vs balance training	SEBT, FADI, (FAAM)	Pakistan
13	Yekdaneh et al.	2024	RCT	29 Athletes with CAI	6 weeks of balance training vs strength training	Proprioception tests, SEBT, FAAM	Turkey
14	Park et al.	2024	Prospective RCT	51 professional adolescent soccer players with FAI	6-week balance & strength (Thera-Band, heel raises)	CAIT, TSK, SEBT	Korea
15	Park et al.	2025	Double-blind, cluster RCT	32 adolescent female basketball players with CAI	6 weeks Hop-stabilisation vs conventional balance training	CAIT, SEBT, T-test, lateral hop, figure-8 hop	Korea

*: The two studies have the same set of populations, but the outcome measures used are different in both studies. Hence, we are considering the population only once.

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