

Effect of Balance And Proprioceptive Training on Athletic Performance in Athletes: A Systematic Review of Randomized Controlled Trials

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Abstract

Background: Athletes frequently suffer from balance and proprioceptive deficits, which are linked to poor neuromuscular control, decreased postural stability, and a decline in sport-specific performance. Although balance and proprioceptive training are frequently utilized to improve functional performance and lower the risk of injury, contradictory results have been found due to differences in intervention procedures and end measures among various sports populations.

Objective: The objective of this systematic review was to assess and collect data from randomized controlled trials (RCTs) regarding the impact of proprioceptive training and balance on athletes' neuromuscular function, balance, and sport-specific results.

Methods: Many electronic databases, including Google Scholar, PubMed, PEDro, Cochrane Library, Web of Science, and Scopus, were thoroughly searched. Research that examined the impact of balance and/or proprioceptive training interventions in athletic populations through randomized controlled trials was included. Agility, coordination, dynamic balance (Star Excursion Balance Test, Y-Balance Test), and sport-specific performance metrics were among the outcome measures. Research with non-randomized designs or non-athletic populations was not included. The Physiotherapy Evidence Database (PEDro) scale was used to evaluate the methodological quality.

Results: Twelve randomized controlled trials involving athletes from sports like soccer, taekwondo, volleyball, badminton, fencing, and kayaking that were published between 2006 and 2025 satisfied the inclusion criteria. The majority of research showed notable gains in dynamic balance, especially in tests like the Y-Balance Test and SEBT reach distances. While balance training improved postural stability and functional performance, proprioceptive training greatly increased agility, coordination, and movement control. When compared to single-mode training, multicomponent therapies that included balancing, proprioceptive, plyometric, and core strengthening exercises showed better results. Additionally, improvements in neuromuscular performance, such as improved coordination and movement efficiency, were noted in a number of trials. Training treatments were substantially more successful than control or traditional training, according to between-group comparisons ($p < 0.05$).

Conclusion: Strong evidence that balance and proprioceptive training are useful therapies for enhancing athletes' dynamic balance, neuromuscular control, and sport-specific performance is provided by this systematic review. Programs for injury prevention and physical conditioning should include multicomponent training techniques since they seem to provide extra advantages. Standardizing training regimens and assessing long-term impacts across various athletic populations should be the main goals of future study.

Keywords: Proprioception, athletes, dynamic balance, neuromuscular control, sport performance, randomized controlled trials, and balance training.

Introduction

Coaches, sports scientists and clinicians are usually in search of new training procedures that will increase the probability of their athletes in their quest to achieve optimal performance. One of the numerous methods of training athletes to play sport is balance and proprioceptive training, which is a component of neuromuscular training, and has an extensive history of both injury rehabilitation and sport. Proprioception is the conscious and unconscious awareness of joint position, motion and force, and it is an inherent awareness of the position of our body in space [M. T. Boraczynski et al., 2018].

Athletic performance is a multidimensional construct that is affected by physical, neuromuscular, and cognitive factors, strength, coordination, agility, and postural control. Balance and proprioception are also viewed as the basic components that allow athletes to perform movements effectively and to prevent injuries [Mazbouh et al., 2023].

Balance, which is the capability to balance the centre of mass of the body on the base of support, is very important

in the static and dynamic sporting activities. It is controlled by means of visual-vestibular-somatosensory integration, which implies the role of the central nervous system (CNS) in motor control [Daneshjoo et al., 2012].

Proprioception is the skill of the body to determine the position of joints, movement and force so that the athletes can be able to make correctly coordinated and accurate movements. It is based on mechanoreceptors that are located in muscles, tendons, ligaments, and joints and that constantly give feedback to the CNS [Arguz et al., 2025].

Proprioceptive input and motor output should be integrated to enable efficient neuromuscular control to help athletes adjust to changing environments. Neuromuscular training is also beneficial in the improvement of motor learning, coordination, and reaction time, which positively lead to the overall sports performance [Mazbouh et al., 2021]. Balance training has been demonstrated to have a significant effect on physical fitness aspects including strength, power, speed and agility.

Equally, proprioceptive training has proven to have a positive impact on reaction time and movement efficiency which are important performance determinants in high-speed sports [Arguz et al., 2025].

Balance training with plyometric or strength training, can further improve neuromuscular adaptations, leading to better agility, stability, and sport-specific performance [Zhou et al., 2022].

In general, although the benefits of balance and proprioceptive training on sport performance are well supported by substantial evidence, recent systematic reviews show that there are significant limitations that need to be addressed by future research. The fact that training procedures are variable, with variations in their length, intensity, frequency and type of exercise complicates the need to establish optimal training parameters that will result in the best performance outcomes. Also, inconsistent results in all performance indices imply that not every aspect of athletic performance is equal to such interventions [Wang et al., 2025].

Moreover, despite the demonstrated benefits of proprioceptive training as a means of improving balance, neuromuscular control, technical skills, and injury prevention, a lack of standardized methods and insufficient studies on the subject of sport-specific training and intermediate level performance outcomes. Gap in knowledge about the impact of age, gender, level of training, and sport type on training effectiveness is also highlighted in existing literature [Yilmaz et al., 2024].

Thus, more systematic research is necessary in order to set the standard training protocols and also investigate the twofold impact of the balance and proprioceptive training on overall athletic performance hence closing the gap between the theoretical and practical aspects of sports in terms of its application in the sporting environment.

Method:

Search Strategy

A systematic search was conducted across the following databases: Google Scholar, PubMed, PEDro, Web of Science, Cochrane Library, and Scopus, to identify randomized and controlled trials evaluating the effect of balance and proprioceptive training on athletic performance in athletes.

The specific terms used for the search included: “balance training,” “proprioceptive training,” “neuromuscular training,” “sensorimotor training,” “athletic performance,” “sports performance,” “agility,” “reaction time,” and “athletes.”

Additionally, relevant Medical Subject Headings (MeSH terms) such as “proprioception,” “postural balance,” and “motor performance” were applied where applicable and combined using Boolean operators “AND” and “OR” to refine the search strategy. Table 1 of the supplementary material shows the search strategy for the different databases included. To complete the systematic literature search, the references of eligible articles were examined; articles were first selected by keywords, then by title and abstract, and finally, the full text was read.

Study Selection

Studies had to meet the following inclusion criteria:

(i) Randomized controlled trials (RCTs) or controlled experimental studies (ii) Both male and female athletes or physically active individuals (iii) Studies involving balance training, proprioceptive training, or neuromuscular training interventions (iv) Studies assessing athletic performance outcomes such as balance, agility, strength,

power, reaction time, coordination, or sport-specific skills (v) Studies comparing training interventions with control groups, other training methods, or combined interventions (vi) Articles published in the English language.

The exclusion criteria were:

(i) Case reports, narrative reviews, systematic reviews, or meta-analyses (ii) Studies not involving a training intervention (iii) Studies focusing solely on clinical or rehabilitation populations without athletic relevance (iv) Studies involving participants who had undergone recent surgical interventions or acute injuries (v) Articles with insufficient data or incomplete reporting of outcomes.

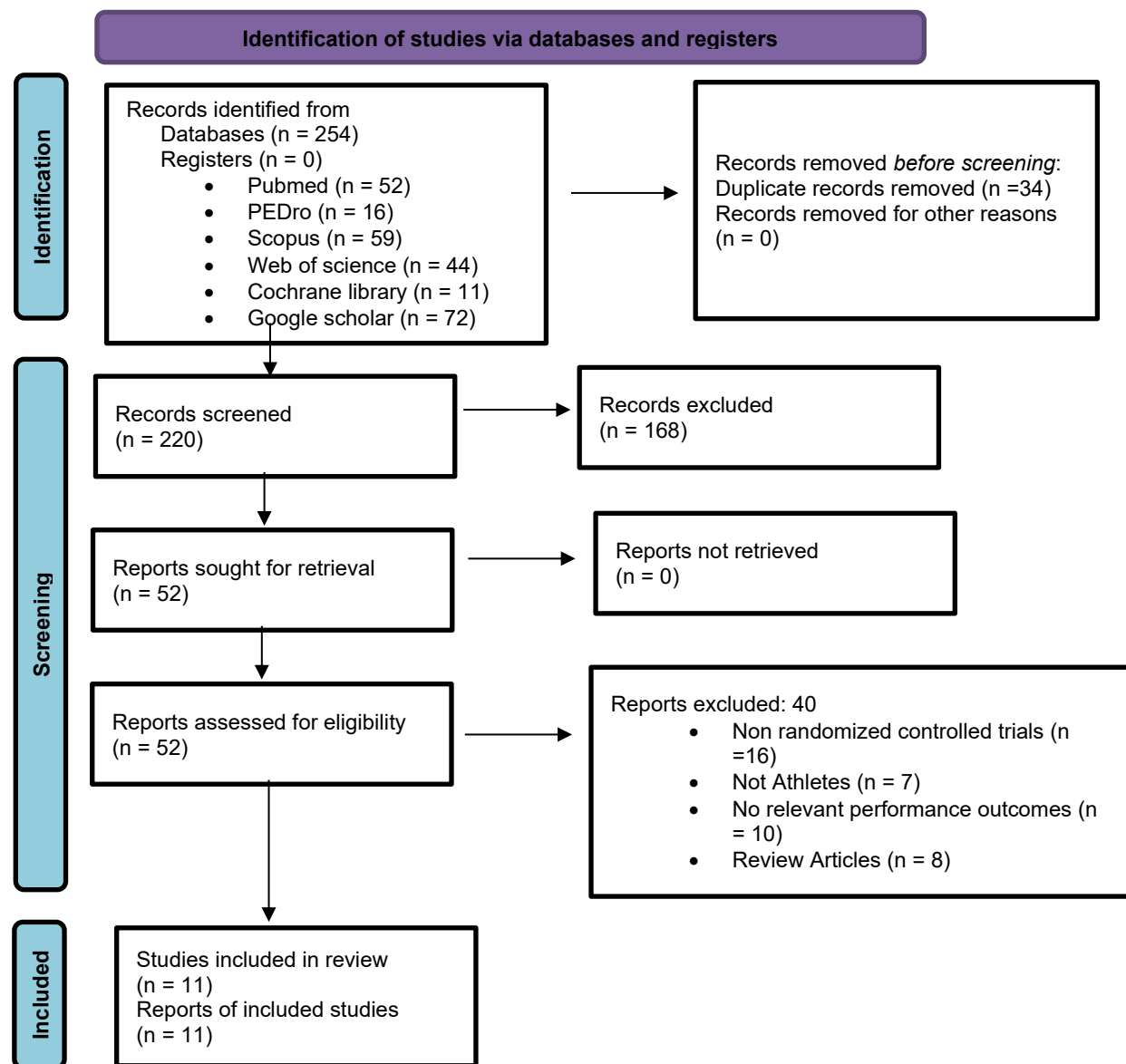


FIGURE 1 Flowchart of the study selection process

Data extraction, methodological quality, and risk of bias assessment

From each included study, information was collected on the author and the year of publication, participant demographics, sport type, sample size, details of the intervention protocol (including training duration and frequency), outcome measures, and the key findings of the study.

The Methodological quality of the included studies was evaluated by using the

Physiotherapy Evidence Database (PEDro) scale. The assessment revealed that two articles were of fair quality, and ten were of good quality.

Sno	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 and variability	Total
1.	Tayshete et al., 2020	1	1	0	1	0	0	0	1	0	1	1	6
2.	Gioftsidou et al., 2006	1	1	0	1	0	0	0	1	0	1	1	6
3.	Daneshjoo et al., 2022	1	1	0	1	0	0	0	1	0	1	1	6
4.	Daneshjoo et al., 2012	1	1	0	1	0	0	0	1	0	1	1	6
5.	Mitrousis et al., 2023	1	1	0	1	0	0	0	1	0	1	1	6
6.	Yarayan et al., 2025	1	1	1	1	0	0	0	1	1	1	1	8
7.	Yoo et al., 2018	1	1	0	1	0	0	0	1	0	1	1	6
8.	Gao et al., 2025	1	1	1	1	0	0	0	1	1	1	1	8
9.	Zhou et al., 2022	1	1	0	1	0	0	0	1	0	1	1	6
10.	Salot et al., 2020	1	1	0	1	0	0	0	1	0	1	1	6
11.	Shen et al., 2024	1	1	0	1	0	0	0	1	0	1	1	6

Result/Findings

Systematic Review

Twelve studies (Gioftsidou et al., 2006; Daneshjoo et al., 2012; Yoo et al., 2018; Daneshjoo et al., 2022; Zhou et al., 2022; Mitrousis et al., 2023; Charmi Salot et al., 2020; Shen et al., 2024; Tayshete et al., 2020; Yarayan et al., 2025; Gao et al., 2025) examined the effects of balance and proprioceptive training on balance, neuromuscular performance, and sport-specific outcomes (Figure 1).

The studies included were published in the year 2006 to 2025 and were all randomized controlled trials (RCTs)

performed in various countries, among them Greece, Iran, Korea, China, Turkey, and others. All the studies involved a total of about 350-400 participants (mainly adolescent and young athletes). Participating age was mostly between 11 and 25 years, which is determined by the sport and the population being studied.

The experimental groups were subjected to balance and proprioceptive training interventions whereas the control groups were subjected to conventional training, alternative exercise programs or no training.

Most studies utilized standardized balance assessment tools, including the Star Excursion Balance Test (SEBT) and the Y-Balance Test to measure balance outcomes, with some studies also assessing balance outcomes on force platforms, stability systems, or sport-specific balance tests (Mitrousis et al., 2023; Gioftsidou et al., 2006; Gao et al., 2025, Yoo et al., 2018, Tayshete et al., 2020).

To measure proprioceptive and neuromuscular outcomes, the following measures were used: reaction time tests, agility tests, coordination assessments, movement performance variables (Charmi Salot et al., 2020, Yoo et al., 2018; Yarayan et al., 2025; Zhou et al., 2022, Charmi Salot et al., 2020).

Some studies evaluated sport-specific performance outcomes based on the parameters of jump performance, dribbling, passing accuracy, paddling performance, and agility tasks, which reflected improvements in aspects of functional relevance to athletic performance (Mitrousis et al., 2023; Gao et al., 2025; Shen et al., 2024, Charmi Salot et al., 2020).

The training interventions were comprised of balance exercises (static and dynamic), unstable surface training, proprioceptive training, core muscle strengthening, plyometric training, and combined neuromuscular training programs. Control groups usually underwent conventional strength training, regular sports training or no particular balance training.

S. No.	Author	Year	Study Design	Participants	Intervention	Outcome measures	Country
1.	Tayshete et al.	2020	RCT	45 taekwondo athletes	Proprioceptive vs Core vs Control	Y- balance test, Single leg hop test	India
2.	Gioftsidou et al.	2006	RCT	39 soccer players	Balance training before vs after	Balance ability(biodex), knee joint movement	Greece
3.	Daneshjoo et al.	2022	RCT	24 handball players	Warm up program vs control	Dynamic balance (biodex,YBT)	Iran
4.	Daneshjoo et al.	2012	RCT	36 male soccer players	Fifa 11 +& HarmoKnee vs control	Proprioception, static and dynamic balance(SEBT)	Iran
5.	Mitrousis et al.	2023	RCT	32 soccer players	Balance training vs control	Balance, Technical skills	Greece
6.	Yarayan et al.	2025	RCT	22 fencing athletes	Life knetik training vs control	Balance, Agility, Jump, Cognition	Turkey
7.	Yoo et al.2	2018	RCT	30 taekwondo athletes	Proprioceptive vs strength training vs control	Balance (CoP Variables), stability	South Korea

8.	Gao et al.,	2025	RCT	63 kayakers	Instability vs core vs traditional training	Balance (FBT,SEBT),Performance	China
9.	Zhou et al.	2022	RCT	16 bbadminton players	Balance + Plyometric vs plyometric	Knee function, Balance, Proprioception	China
10.	Charmi Salot et al.	2020	RCT	90 male football player	Proprioceptive training (BOSU) vs control	Agility (T agility test)	India
11.	Shen et al.	2024	RCT	30 taekwondo athletes	Balance + Plyometric vs plyometric	Dynamic balance, Agility (DPSI, TAST)	China

Outcome Measures

All the studies focused primarily on proprioception, balance, and performance outcomes. Dynamic balance was commonly assessed by standardised tests like the Y-balancing Test, the Star Excursion Balance Test (SEBT), and various balancing exercises (Mitrousis et al., 2023; Gioftsidou et al., 2006; Gao et al., 2025, Daneshjoo et al., 2012, 2022, Yoo et al., 2018, Shen et al., 2023). Athletic performance (coordination, speed, agility, reaction time) was also frequently assessed. Proprioceptive training led to significant improvements in reaction time, Agility and neuromuscular response, indicating improved psychomotor performance (Charmi Salot et al., 2020, Yoo et al., 2018, Shen et al., 2023, Yarayan et al., 2025).

It is worth noting that one study included not only proprioceptive training but core muscle strengthening interventions, and assessed the results with the Y-Balance Test and Single Leg Hop Test, thus, including a dynamic balance, neuromuscular control, and lower limb functional performance evaluation (Tayshete et al., 2020).

Additionally, several studies that measured sport-specific performance such as passing, paddling, dribbling, jump performance, and movement control demonstrated improved performance (Mitrousis et al., 2023; Shen, 2024, Daneshjoo et al., 2012, Gao et al., 2025).

Some studies also looked at biomechanical and neuromuscular measures, such as postural control, muscle activation, joint position sense, and movement patterns. These measures reveal the underlying mechanisms that lead to improved performance (Gao et al., 2025; Yarayan et al., 2025; Zhou et al., 2022; Yoo et al., 2018).

Effects of Balance Training and Proprioceptive training

Balance and Proprioceptive Outcomes

The majority of the included studies found that proprioceptive and balance training interventions significantly improved balance-related outcomes. Dynamic balance was regularly assessed using the Star Excursion Balance Test (SEBT), Multidirectional Balance Exercises, and Y Balance test with consistently better outcomes (Mitrousis et al., 2023; Gioftsidou et al., 2006; Gao et al., 2025, Daneshjoo et al., 2012, 2022, Yoo et al., 2018, Shen et al., 2023, Tayshete et al., 2020). These increases were significantly greater in training groups than in control or conventional training groups in the majority of trials.

Following proprioceptive training programs, a number of studies found improvements in proprioceptive outcomes in addition to balance. Improvements in movement awareness, joint position sensing, and performance-related aspects like coordination, speed, agility, and reaction time were also routinely assessed (Charmi Salot et al., 2020, Yoo et al., 2018, Tayshete et al., 2020, Shen et al., 2023, Yarayan et al., 2025). These results suggest that increasing neuromuscular control and stability in athletes is mostly dependent on proprioceptive training and balance.

Sports Specific Performance Outcomes

Numerous studies evaluated performance factors specific to a given sport, including passing, dribbling, agility, change of direction, and movement performance. Significant increases in these performance components were shown by balance and proprioceptive training, suggesting improved functional ability in athletic tasks (Charmi Salot et al., 2020; Yoo et al., 2018, Tayshete et al., 2020, Shen et al., 2023, Yarayan et al., 2025).

Balance training, especially when performed on unstable surfaces and with multidirectional movements, showed improvements in agility and change-of-direction speed, suggesting better dynamic control during the performance of sport skills (Mitrousis et al., 2023; Gioftsidou et al., 2006; Gao et al., 2025, Daneshjoo et al., 2012, 2022, Shen et al., 2023). Proprioceptive training, such as joint position and coordination training, elicited improvements in movement accuracy, reaction-based performance and technical skills (Tayshete et al., 2020, Yoo et al., 2018).

Multidimensional training programs involving both balance and plyometric or sport-specific tasks showed the greatest effects on performance outcomes, such as agility, coordination and technical skills (Zhou et al., 2022; Shen, 2024). Furthermore, balance training that was specific to sports enhanced passing, dribbling, and movement efficiency, indicating the transferability of training effects to performance during sports (Mitrousis et al., 2023).

Neuromuscular and Biomechanical Outcomes

Numerous included studies showed that proprioceptive training and balance interventions greatly enhanced neuromuscular performance, including coordination, muscle activation, movement control, and stability, all crucial elements of athletic performance (Yarayan et al., 2025, Tayshete et al., 2020, Yoo et al., 2018).

Balance training interventions demonstrated improvements in postural control, muscular coordination, and control, resulting in improved performance during sports tasks (Gao et al., 2025, Gioftsidou et al., 2006). These findings demonstrate improved neuromuscular processing post-training interventions.

Compared to single training interventions, multi-component training interventions including balance, proprioception, plyometric and strength training interventions produced greater increases in coordination, movement control and performance (Zhou et al., 2022; Shen, 2024, Yoo et al., 2018, Tayshete et al., 2020).

Between Group Comparison

Comparative studies between proprioceptive training and muscular strength training found that both training approaches improved balance and performance; however, proprioceptive training was more likely to produce changes in dynamic balance and postural control, while muscular strength training was more likely to affect isolated muscle strength (Yoo et al., 2018, Tayshete et al., 2020).

Likewise, studies that investigated combined training programs found that balance training combined with plyometric training led to greater improvements in dynamic balance and functional performance compared with traditional or single training interventions (Shen, 2024). Combined training improved agility, coordination and control of movement in participants.

Likewise, a combined balance and plyometric training program was demonstrated to improve knee function, dynamic balance and performance measures, which suggested it was more effective than single-mode training programs (Zhou et al., 2022).

Discussion

According to this review, proprioceptive and balance training greatly enhances athletes' neuromuscular control, dynamic balance, and sport-specific performance. Using tests like the SEBT and Y-Balance Test, the majority of studies found improved postural stability, which suggests improved sensorimotor integration. Reaction time, coordination, and movement control all improved with proprioceptive training, indicating increased neuromuscular efficiency.

Better sport-specific performance, including agility, direction change, and technical abilities like jumping and movement execution, resulted from these advancements. The best results were obtained from programs that combined core strengthening, plyometric activities, and balance training, demonstrating the efficacy of multicomponent training techniques.

All things considered, adding proprioceptive training and balance to athletic regimens can improve performance and possibly lower the chance of injury. However, different study designs and a modest level of methodological quality indicate that future research should focus on larger, better trials using uniform protocols.

Conclusion

According to this comprehensive review, proprioceptive training and balance are useful interventions for enhancing athletes' neuromuscular control, dynamic balance, and sport-specific performance. These training techniques improve movement efficiency, coordination, postural stability, and reaction time—all of which are critical for peak athletic performance.

When compared to single-mode therapies, multicomponent training programs that incorporate balance, proprioceptive, plyometric, and core strengthening activities seem to offer more advantages. These integrated approaches improve overall functional performance and support better movement control during sport-specific tasks.

From a practical perspective, incorporating balance and proprioceptive training into regular athletic conditioning programs may also contribute to injury prevention by enhancing joint stability and neuromuscular coordination.

However, due to moderate methodological quality and variability among studies, further high-quality randomized controlled trials with standardized protocols and long-term follow-up are recommended to strengthen the evidence base.

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