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The effects of balance training on physical fitness and skill-related performance in basketball players: a systematic review

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Abstract

Background Existing evidence suggests that balance training (BT) has a positive impact on physical fitness and sports performance. However, its specific effects on basketball players have not been extensively studied. Therefore, this systematic review aims to analyze the influence of BT on the physical fitness and skill-related performance of basketball players.

Method A thorough search was conducted across four databases (Web of Science, Scopus, PubMed, and EBSCOhost) for studies published until August 24, 2024, using keywords related to BT and basketball. The quality of the included studies was assessed using the "Qualsyst" tool.

Results Thirteen studies involving 373 participants were included, focusing on BT interventions lasting a minimum of four weeks. These studies demonstrated that BT led to significant enhancements in balance, power, agility, stability, and basketball skill-related performance. Nevertheless, certain assessments such as the balance error scoring system, triple hop distance, 30-second maximal performance jump, single-leg triple hop, Y reactive agility, and maneuver running tests did not show significant improvements.

Conclusion BT proves to be a valuable intervention for improving physical fitness and skill-related performance among basketball players. However, the variability in training methods highlights the need for further research to determine the optimal BT parameters, including training volume, intensity, and duration. Additionally, future studies should explore how factors such as gender, age, and playing level influence the effectiveness of BT in basketball players.

Keywords Balance, Neuromuscular training, Stability, Sports, Basketball

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Introduction

Basketball is a physically demanding sport that necessitates high levels of physical fitness, including strength, agility, coordination, and balance, all of which significantly impact players' performance during competition [1, 2]. To enhance performance on the court, basketball players participate in various training programs focused on improving elements such as strength, speed, and endurance [3–5]. Among these, balance training has emerged as a crucial tool for improving stability and coordination vital for maintaining control during dynamic movements [6–8].

Balance and proprioception are fundamental components of athletic performance, particularly in sports requiring dynamic movements and rapid directional changes like basketball [9, 10]. Balance training (BT) involves exercises targeting an individual's ability to maintain stability and control over their body's position [8, 11]. It comprises activities challenging the body's equilibrium, improving proprioception, and strengthening stabilizing muscles, especially those in the core and lower limbs [12, 13].

Proprioception, which refers to the body's ability to sense movement and position, contributes to coordination, agility, and injury prevention [14]. It enables athletes to make rapid adjustments in response to external forces, improving neuromuscular coordination and postural stability [15]. The vestibular system, which helps regulate spatial orientation and balance, works alongside proprioception to maintain spatial orientation, stability, and movement control [16], which are crucial for athletic performance.

Proprioceptive training has been shown to enhance athletic abilities across multiple sports such as soccer, taekwondo, and fencing [9]. Research indicates that it can improve agility, reaction time, explosive strength, and skill execution, contributing to better dribbling, passing accuracy, joint stability, and postural control [9]. Given the similarities in movement demands, basketball players may also benefit from proprioceptive training, particularly in tasks requiring rapid directional changes, high-intensity movements, and precise motor control.

BT induces specific physiological adaptations critical for athletic performance, including improved neuromuscular coordination [17], reduced overactive proprioceptive feedback [18], and adaptations within the vestibular system [18]. These adaptations collectively enhance an athlete's ability to perform rapid postural adjustments, maintain dynamic equilibrium, and efficiently execute sport-specific movements [9]. BT is particularly relevant for basketball players who face rapid changes of direction, sudden stops, and dynamic postures [19, 20]. By enhancing neuromuscular control, BT assists players in enhancing stability, lowering fall risks, and enhancing overall performance [17, 21]. Basketball movements such as jumping, landing, cutting, and pivoting necessitate a high level of balance for efficient and safe execution [22]. Incorporating BT into a basketball training regimen has been demonstrated to improve players' movement control, enhancing performance in critical areas like shooting accuracy and defensive agility [23, 24].

While BT has been extensively researched in various sports like soccer [25, 26], volleyball [27, 28], and badminton [29, 30], where stability and control are essential, there are also several systematic reviews examining its impact on sports performance [8, 17, 31, 32]. For example, one systematic review explored BT for enhancing neuromuscular control and performance with healthy and physically active individuals, demonstrating its effectiveness in improving postural and neuromuscular control [17]. Gebel et al. (2018) found that BT is a beneficial training approach to enhance balance performance with moderate to significant effects on static and dynamic balance in healthy youth [31]. Brachman et al. (2017) reviewed 50 studies on BT involving young, healthy athletes aged 7–30 years, with participants ranging from elite competitors and national league players to amateurs and school-level athletes, and most studies indicated improvements in postural control [8]. Despite mounting evidence supporting balance training in enhancing athletic performance across various sports, there is still a lack of research specifically focusing on its effects on basketball players, who face challenges like jumping, cutting, and rapid changes of direction that demand exceptional balance. Considering the dynamic nature of basketball, where maintaining balance during intricate maneuvers is critical, this review aims to explore the effects of BT on physical fitness and skill-related performance in basketball.

Method

Protocol and registration

The study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines [33]. It was registered on the Platform of Registered Systematic Review and Meta-analysis Protocols (INPLASY2024100029) on October 8th, 2024.

Eligibility criteria

Several inclusion criteria were applied according to the PICOS framework: (1) participants were basketball players; (2) the intervention was balance training (BT), lasting at least four weeks; (3) control groups underwent regular training without additional BT; (4) outcomes related to the effects of BT on physical fitness (e.g., power, speed, balance) and basketball performance (e.g., passing, shooting, dribbling); (5) randomized controlled trials (RCTs), non-randomized controlled trials (nRCTs), and non-randomized non-controlled trials (nRnCTs); (6) English articles with full text; The exclusion criteria were: (1) reviews; (2) studies lacking BT as an intervention; (3) unpublished studies.

Information sources and search strategy

The search was conducted on 24 August 2024. The Web of Science, Scopus, PubMed, and SPORTDiscus databases were queried (Table 1). The search terms were: "balanc*" OR "neuromuscular" OR "propriocepti*" OR "sensorimotor" OR "kinaesthetic" OR "instability" OR "stability" OR "perturbation" OR "postural stability" OR "postural control" OR "postural sway" OR "wobble board" OR "balance board" OR "coordination" AND basketball. Additionally, the references of studies and Google Scholar were screened.

Data selection

Duplicates were identified using EndNote X20 software (Thomson Reuters) in New York City, NY, United States. Two authors (SC and JL) independently reviewed the titles, abstracts, and full texts based on the selection criteria. A third author (ZW) compiled and verified the results, and any discrepancies were resolved through discussions with another author (SKG). The inter-reviewer agreement was assessed using the Kappa statistic, calculated with SPSS software (IBM Corp. Released 2022. IBM SPSS Statistics for Macintosh, Version 29.0. Armonk, NY: IBM Corp) to determine inter-reviewer agreement [34].

Data collection

Data collection was independently performed by two authors (SC and JL), including: (1) population characteristics (e.g., age, height, body mass); (2) intervention details; (3) comparison; (4) intervention characteristics (e.g., length, frequency, duration, training protocol, intensity, time of season); (5) measurements; and (6) outcomes. A third author (SKG) validated the results to ensure accuracy.

Quality assessment

The 14-item "Qualsyst", with specific criteria (yes = 2, partial = 1, no = 0), was used to assess the quality of the studies [35] (Table 2). The quality of each included study was independently evaluated by two authors (SC and ZW), and any discrepancies were discussed and resolved via consensus with a third author (SKG). This tool categorized the selected studies into strong quality (75% or higher), moderate quality (55–75%), and poor quality (less than 55%). Studies with poor quality assessment scores were excluded.

Data synthesis

Meta-analyses were not feasible due to the lack of comparable outcome measures collected at consistent time points [36]. Specifically, the studies did not consistently report three or more baseline and follow-up measurements for the same variables. Moreover, there was insufficient homogeneity across the studies concerning the recruited players, interventions administered, and outcomes measured [37]. Consequently, the extracted data were analyzed following the guidelines of the Centre for Reviews and Dissemination [38].

Results

Study selection

A total of 7,313 studies were initially screened. After eliminating duplicates, 5,792 studies remained. Following title and abstract screening, 255 studies underwent a full-text review. These studies were then evaluated based on inclusion and exclusion criteria, resulting in 17 eligible studies. After the quality assessment, four studies

Table 1 Number of hits for the complete search strategy for the databases

Database	Complete Search Strategy	Hits 24th August 2024
PubMed	("balanc*" [Title/Abstract] OR "neuromuscular" [Title/Abstract] OR "propriocepti*" [Title/Abstract] OR "sensorimotor" [Title/Abstract] OR "kinaesthetic" [Title/Abstract] OR "instability" [Title/Abstract] OR "stability" [Title/Abstract] OR "perturbation" [Title/Abstract] OR "postural stability" [Title/Abstract] OR "postural control" [Title/Abstract] OR "postural sway" [Title/Abstract] OR "wobble board" [Title/Abstract] OR "balance board" [Title/Abstract] OR "coordination" [Title/Abstract]) AND (basketball [Title/Abstract])	736
Web of Science	(TS = ("balanc*" OR "neuromuscular" OR "propriocepti*" OR "sensorimotor" OR "kinaesthetic" OR "instability" OR "stability" OR "perturbation" OR "postural stability" OR "postural control" OR "postural sway" OR "wobble board" OR "balance board" OR "coordination")) AND TS = (basketball)	3688
Scopus	balanc* OR "neuromuscular" OR "propriocepti*" OR "sensorimotor" OR "kinaesthetic" OR "instability" OR "stability" OR "perturbation" OR "postural stability" OR "postural control" OR "postural sway" OR "wobble board" OR "balance board" OR "coordination" AND basketball	1788
EBSCOhost (SPORTDiscus)	AB ("balanc*" OR "neuromuscular" OR "propriocepti*" OR "sensorimotor" OR "kinaesthetic" OR "instability" OR "stability" OR "perturbation" OR "postural stability" OR "postural control" OR "postural sway" OR "wobble board" OR "balance board" OR "coordination") and AB basketball	1101

Table 2 Quality assessment through qualsyst

Studies	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	Score	Rating
Mahmoud (2011)	2	1	1	2	0	0	0	2	1	1	2	0	2	1	15	Poor
Nikolaos et al. (2012)	2	2	1	2	0	0	0	2	1	2	2	0	2	2	18	Moderate
Boccolini et al. (2013)	2	2	1	2	2	0	0	2	1	2	2	0	2	2	20	Moderate
Panwar & Narwal (2014)	2	2	2	1	2	0	0	2	2	2	2	0	2	2	21	Strong
Santos et al. (2016)	2	2	2	2	2	0	0	2	1	2	2	0	2	2	21	Strong
Alhawary (2019)	2	2	1	2	N/A	0	0	2	1	2	2	0	2	2	18	Moderate
Yeole & Pawar (2019)	2	2	2	1	2	0	0	2	1	2	2	0	2	2	20	Moderate
Domeika et al. (2020)	2	2	1	2	0	0	0	2	1	2	2	0	2	2	18	Moderate
Sharath et al. (2020)	1	1	2	1	2	0	0	1	1	0	2	0	1	2	14	Poor
Zacharakis et al. (2020)	2	2	1	2	2	0	0	2	1	2	2	0	2	2	20	Moderate
Fisek & Agopyan (2021)	2	2	2	2	2	0	0	2	2	2	2	0	2	2	22	Strong
Lee et al. (2021)	2	2	2	2	2	0	0	2	1	2	2	0	2	2	21	Strong
Hamdan (2023)	2	2	2	2	2	0	0	2	2	2	2	0	2	2	22	Strong
Zhu (2023)	1	1	1	2	2	0	0	2	1	0	2	0	1	2	15	Poor
Lee et al. (2023)	2	2	2	2	2	0	0	2	1	2	2	0	2	2	21	Strong
Lin (2023)	1	1	1	2	2	0	0	0	1	0	2	0	1	2	13	Poor
Boonsom & Bungmark (2024)	2	2	2	1	2	0	0	2	2	2	2	0	2	2	21	Strong

Note. 2 indicates yes, 1 indicates partial, 0 indicates no, N/A not applicable, I question described, II appropriate study design, III appropriate subject selection, IV characteristics described, V random allocation, VI researchers blinded, VII subjects blinded, VIII outcomes measure well defined and robust to bias, IX sample size appropriate, X analytic methods well described, XI estimate of variance reported, XII controlled for confounding, XIII results reported in detail, and XIV conclusion supported by results were excluded, leaving 13 studies for the final analysis. The initial inter-reviewer agreement, as assessed by the Kappa statistic, was 0.817. Two discrepancies during the screening process were resolved through discussion with a third author. Subsequently, the Kappa statistic for the inter-reviewer agreement reached 1.00 during the full-text screening phase (Fig. 1).

Study quality assessment

According to "Qualsyst", seven of the included studies were of high quality, six studies had moderate quality, and four studies having poor quality were removed [39–42] (Table 2).

Participant characteristics

The population characteristics of the 13 studies were presented as follows (Table 3):

(1) Sample size: In total, 373 participants were included across all studies, with sample sizes ranging from 30 [24, 43] to 326 [44] participants, and a mean sample size of 93.09 participants (SD = 80.).
(2) Sex: Six studies focused on male basketball players [45–50], while four studies examined females [23, 24, 43, 51], and three studies included both males and females [44, 52, 53].
(3) Level: Five studies looked into professional basketball players [43, 46, 48, 51, 53], four studies explored collegiate basketball students [23, 47, 49, 50], one study involved recreational basketball players [45], one study focused on both professional and recreational basketball players [24], and two studies did not specify the playing level of participants [44, 52].

Intervention characteristics

The characteristics of the included studies were as follows:

(1) Training program length: The duration of the training programs varied from 4 weeks [44, 53] to

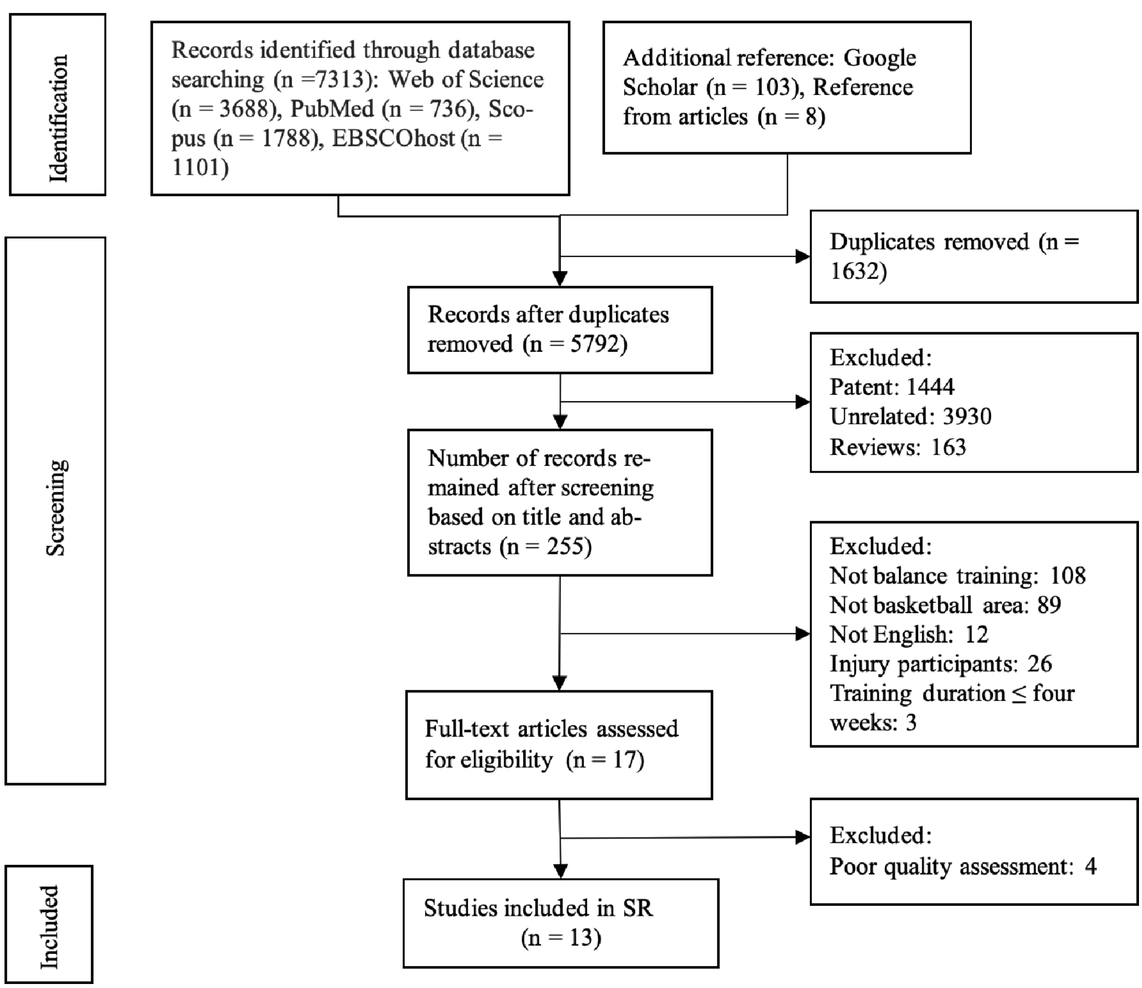

Fig. 1 Systematic review search and screening procedure

Table 3 Data extraction from selected articles

References	Population	I	C	Intervention Characteristics			Measurement	Outcome	
				Len/F/D	TP	Season		Time	BetweenGroups
Nikolaos et al. [45]	*N* = 26 M; TB: NR; EG: A = 22.7 ± 0.7 years, H = 188.4 ± 3.3 cm, BM = 95.6 ± 2.9 kg; CG: A = 21.6 ± 0.7 years, H = 190.4 ± 2.7 cm, BM: 94.0 ± 3.1 kg; PL: recreational	BT	CG	Len: 12 weeks; F: NR; D: NR	BT was implemented based on tools including the balance disc, Bosu ball, Togu ball, and trampoline	NR	BP: passing skills	EG: passing skills ↑; CG: passing skills ↑	Passing skills ↑ in EG vs. CG
Boccolini et al. [46]	*N* = 23 M; TB: NR; EG: A = 15.0 ± 0.0 years, H = 180.1 ± 2.4 cm, BM = 69.6 ± 3.0 kg; CG: A = 14.6 ± 0.1 years, H = 178.6 ± 2.6 cm, BM: 65.5 ± 1.7 kg; PL: professional	BT	CG	Len: 12 weeks; F: 2 sessions / week; D: 30 min	8 sets of 20-s of Swiss-Ball kneeling hold balancing with 30-s of recovery; 6 sets of 20 repetitions of the two-handed chest pass balance exercise on Trial-T1 half-sphere with 30-s recovery; 10 sets of 30-s per limb of the single-leg balance with 10-s of recovery between repetitions and alternating the supporting lower limb	Pre-season	Balance: balance test using the Libra board; Power: CMJ	EG: all ↑; CG: all ↔ except left leg balance test	All ↑ in EG vs. CG
Panwar & Narwal [47]	*N* = 50 M; TB: 1 year at least; A = 18–22 years, H: NR, BM: NR PL: collegiate	BT + RT	RT	Len: 8 weeks; F: 3–5 sessions /week; D: NR	Open or close eyes on the floor or wobble board with single-leg or double-leg stance	In-season	Balance: dynamic balance using BESS, static balance using SEBT; Power: triple hop distance	EG: Balance ↑, power ↔ CG: Balance ↔, power ↑	Balance ↑, power ↔ in EG vs. CG
Santos et al. [51]	*N* = 22 FM; TB: 5 years at least; EG: A = 18.0 ± 6.5 years, H = 167.8 ± 7.5 cm, BM = 65.0 ± 8.0 kg; CG: A = 17.8 ± 6.1 years, H = 166.4 ± 9.1 cm, BM: 64.6 ± 15.3 kg; PL: professional	BT	CG	Len: 6 weeks; F: 3 sessions / week; D: 5–9 min	Slackline training; 3 reps * 30-s exercise * 10-s interval	In-season	Power: CMJ, 30-s maximal performance jump test; Balance: CoP measurements	EG: CMJ, CoP measurements ↑, 30-s maximal performance jump test ↔; CG: all ↔	CMJ and CoP measurements ↑, 30-s maximal performance jump test ↔ in EG vs.CG
Alhawary [43]	*N* = 10 FM; TB: NR; EG1: A = 14.6 ± 0.5 years, H = 172.5 ± 3.1 cm, BM = 76.2 ± 4.6 kg; PL: professional	BT	N/A	Len: 8 weeks; F: 5 sessions / week; D: 40 min	Dynamic BT such as coordination ladder training, dot, plyometrics, Hexagon form; 2–3 sets with 30-50-s rests between sets, 15-30-s exercises with 10–15 rests between exercises	NR	Balance: MFT device test; Power: VJ; Agility: hexagon test; BP: shooting tests	EG: all ↑	N/A
Yeole & Pawar [44]	*N* = 60 FM + M; TB: NR; A = 14–25 years, PL: NR	EG1: sports-specific BT; EG2: BT	N/A	Len: 4 weeks; F: NR; D: NR	NR	NR	Balance: SEBT; COD: MZZDT	EG1: all ↑; EG2: all ↑	All ↑ in EG1 vs. EG2

Table 3 (continued)

References	Population	I	C	Intervention Characteristics			Measurement	Outcome	
				Len/F/D	TP	Season		Time	BetweenGroups
Domeika et al. [50]	*N* = 31 M; TB: NR; A = 21.4 ± 0.6 years, H = 191.0 ± 1.9 cm, BM = 87.0 ± 2.6 kg; PL: collegiate	basketball-specific BT	CG	Len: 8 weeks; F: 3 sessions / week; D: 20 min	The BT was complimented on an unstable platform called Abili Balance Trainer with or without an elastic band, or with a basketball	In-season	Balance: YBT, PST	EG: all ↑; CG: Y balance test ↔, PST ↓	NR
Zacharakis et al. [52]	*N* = 25 FM, 30 M; TB: 3 years; EG1: A = 13.0 ± 0.2 years, H = 169.7 ± 1.7 cm, BM = 59.9 ± 2.4 kg; EG2: A = 13.0 ± 0.2 years, H = 164.5 ± 1.2 cm, BM = 56.5 ± 1.4 kg; CG1: A = 13.0 ± 0.1 years, H = 162.5 ± 2.1 cm, BM:58.0 ± 2.8 kg; CG2: A = 13.0 ± 0.2 years, H = 158.3 ± 1.1 cm, BM:54.8 ± 2.0 kg; PL: NR	BT	CG	Len: 8 weeks; F: 3 sessions / week; D: 14–26 min	BT was implemented on tools including BOSU balls, mini trampolines, wobble boards, balance beams, agility ladders, hoops, and obstacles	NR	Balance: dynamic balance using stability platform-lafayette, static balance by standing on a wooden surface; BP: fast shooting, passing, and dribbling test, defensive sliding test, lay-up test; COD: no ball maneuver running	EG1: balance, fast shooting, passing ↑, others ↔; EG2: dynamic balance, passing, defensive sliding, and lay-up tests ↑, others ↔ CG1 and CG2: all ↔	Balance, shooting, and passing tests ↑ in EG vs. CG
Fisek & Agopyan [48]	*N* = 25 M; TB: 4.2 ± 1.1 years; EG1: A = 15.6 ± 0.65 years, H = 178.6 ± 7.0 cm, BM = 71.7 ± 9.4 kg; EG2: A = 15.6 ± 0.5 years, H = 177.4 ± 8.1 cm, BM: 67.8 ± 7.9 kg; PL: professional	EG1: BT on unstable surface; EG2: BT on stable surface	N/A	Len: 6 weeks; F: 2 sessions / week; D: 35–50 min	BT including Busso balance disc exercises, delta balance ball exercises on the unstable or stable surface, and trampoline exercises; 3 sets * 20-3-s or 5–21 reps with 10-60-s rests	In-season	Balance: YBT; Stability: closed kinetic chain upper extremity stability test; BP: passing accuracy and speed	EG1: all ↑; EG2: all ↑ except passing speed ↔	All ↑ except passing speed ↔ in EG1 vs. EG2
Lee et al. [53]	*N* = 14 FM, 11 M; TB: 8.4 ± 2.2 years; A = 18.0 ± 2.2 years, H = 1872.5 ± 9.4 cm, BM = 71.9 ± 8.9 kg; PL: professional	EG1: BT EG2: PT	CG	Len: 4 weeks; F: 2 sessions / week; D: 15 min	Standing on a dyna-disc or Airex pad progressing to a single leg squat, supine straight leg bridge on a physioball, lunge on Airex ad or BOSU ball progressing to lunge with dumbbells, a bilateral squat with bar placed on shoulders using Airex progressing to BOSU ball; 1–2 sets * 8–15 reps	NR	Power: single leg triple hop; Balance: BESS; Agility: reactive agility	EG1: all ↔; EG2: all ↔; CG: all ↔	NR

Table 3 (continued)

References	Population	I	C	Intervention Characteristics			Measurement	Outcome	
				Len/F/D	TP	Season		Time	BetweenGroups
Hamdan [23]	N = 20 FM; TB: NR; EG: A = 18.9 ± 0.3 years, H = 171.6 ± 1.4 cm, BM = 62.5 ± 1.0 kg; CG: A = 18.8 ± 0.4 years, H = 171.9 ± 1.1 cm, BM = 62.8 ± 0.8 kg; PL: collegiate	BT	CG	Len: 8 weeks; F: 3 sessions / week; D: 60 min	BT was implemented with medicine balls, BOSU ball, cushion balls, fit ball, a cylindrical plank, a sponge mattress	NR	Dribbling skills: inbound dribbling, quick and zigzag dribbling between signs, dribble between cones; Shooting skills: traditional forward shot, jump shot after passing between corns, jump shot after receiving the ball, jump shot after passing between cones	EG: all ↑; CG: all ↔	All ↑ in EG vs. CG;
Lee et al. [24]	N = 10 FM; TB: 2 years at least; EG: A = 22.4 ± 1.3 years, H = 169.8 ± 5.6 cm, BM = 64.0 ± 14.2 kg; CG: A = 23.6 ± 0.9 years, H = 170.6 ± 5.7 cm, BM = 67.6 ± 11.4 kg; PL: professional + recreational	BT	CG	Len: 6 weeks; F: 3 sessions / week; D: 30–45 min	BT with perturbation intervention; The BT included the tandem stance, split squat stance, single leg stance, bilateral jumping and landing, and single leg jumping and landing; The perturbation included the different number of disturbances, speed of pertubations, predictability	NR	YBT	EG: YBT ↑; CG: YBT ↔	YBT ↑ in EG vs. CG;
Boonsom & Bungmark [49]	N = 16 M; TB: 2 years at least; A: NR, H: NR, BM: NR; PL: collegiate	BT	CG	Len: 8 weeks; F: 3 sessions / week; D: 60 min	Balance shooting training; Focus on exercises like one-foot jumps, lunges, and single-leg hops combined with shooting during week 1–4; Introduced more complex movements like 360-degree jumps and handoff dribble turns followed by jump shots during week 5–8	NR	Balance: YBT; BP: jump shot test	EG: all ↑; CG: YBT ↑, shooting skills ↔	shooting skills ↑, YBT ↔ in EG vs. CG;

Note. A, age; H, height; BM, body mass; PL, playing level; M, male; FM, female; PT, plyometric training; NR, not reported, N/A, not applicable; CG, control group; EG, experimental group; F, frequency; D, duration; Len: length; I, intervention; C, comparison; TP, training protocol; BT, balance training; BP, basketball performance; RT, regular training; CMJ, countermovement jump; VJ, vertical jump; SEBT, star excursion balance test; MZZDT, mini zig zag drill test; MFT, multi-functional trainer; YBT, Y balance test; PST, postural stability test; COD, change of direction; BESS, balance error scoring system; ↑, significantly positive effect; ↓, significantly negative effect; ↔, no effect;

12 weeks [45, 46], with a mean length of 7.5 weeks (SD = 2.5).

(2) Training frequency: Eleven studies provided details on the intervention frequency, which ranged from 2 to 5 times per week. Two studies did not specify the frequency [44, 45].

(3) Training duration: Ten studies specified the duration per training session, ranging from 5 min to 60 min. Three studies did not provide this information [44, 45, 47].

(4) Training session: Four studies conducted the balance training during the in-season [47, 48, 50, 51], and one in the pre-season [46]. Other studies did not specify the training session.

Outcome characteristics

Effect of BT on balance

Eleven selected studies examined the impact of balance training (BT) on balance using assessment tools such as the Libra board test [46], balance error scoring system (BESS) [47, 53], star excursion balance test (SEBT) [44, 47], CoP measurements [51], multi-functional trainer (MFT) device test [43], Y balance test (YBT) [24, 48–50], postural stability test (PST) [50], stability platform-lafayette [52], and standing on a wooden surface test [52]. With the exception of two studies reporting unchanged results for BESS [53] and the stability platform-lafayette test [52], all balance performances significantly improved in the selected studies.

Effect of BT on power

Five studies investigated the effect of BT on power using assessment tools such as countermovement jump (CMJ) [46, 51], vertical jump (VJ) [43], triple hop distance test [47, 53], and 30-s maximal performance jump test [51]. The CMJ and VJ showed significant improvement after BT, whereas the triple hop distance test and 30-s maximal performance jump test did not show significant improvement.

Effect of BT on agility

Four studies investigated the effect of BT on agility using assessment tools such as the hexagon test [43], Y reactive agility test [53], mini zig zag drill test (MZZDT) [44], and maneuver running test [52]. The hexagon test and MZZDT significantly improved following BT, while the Y reactive agility test and maneuver running test did not exhibit significant improvement.

Effect of BT on stability

Only one study explored the effect of BT on stability using the closed kinetic chain upper extremity stability test, which showed significant improvement after BT [48].

Effect of BT on basketball performance

Six studies investigated the impact of BT on basketball performance, including passing tests [45, 48, 52], shooting tests [23, 43, 49, 52], dribbling tests [23, 52], defensive sliding test [52] and lay-up test [52]. All basketball performance metrics significantly improved after BT, except for one study reporting unchanged results for fast shooting, dribbling, defensive sliding, and lay-up tests [52].

Discussion

This systematic review aimed to investigate the effects of balance training (BT) on the physical fitness and skill-related performance of basketball players. The results suggest that BT can significantly improve balance, power, agility, stability, and basketball performance. However, some tests showed insignificant improvements, as discussed below.

Effect of BT on balance

Balance encompasses dynamic and static aspects. Both are crucial for basketball players. In this review, ten studies showed that BT has a significant positive impact on balancing ability. It exhibited in improving static balance in tests like the Libra board test, SEBT, CoP measurements, standing on a wooden surface test, and PST, and dynamic balance in tests like BESS, stability platform-lafayettes test, MFT device test, and YBT. These results corroborate a previous systematic review demonstrating BT's effectiveness in enhancing static and dynamic balance in young athletes [54].

The enhancement can be attributed to various interventions used in the ten studies. Firstly, balance exercises require continuous adjustment of muscle activation patterns [55], improving coordination and muscle group recruitment. Utilizing unstable surfaces like BOSU balls or wobble boards challenges the neuromuscular system, aiding in stabilization against perturbations [56]. Training involving perturbation, such as slackline and trampoline exercises, enhances equilibrium maintenance during movement [57]. Additionally, exercises like the Libra board test, SEBT, and slackline training enhance proprioception, improving sensory feedback from joints, tendons, and muscles, thereby enhancing joint stability, crucial for balance [58, 59].

However, few studies have reported insignificant results in balance-related assessments. For instance, Lee et al. (2021) did not observe a significant improvement in BESS with BT. One possible factor could be the differences in participant characteristics, such as experience and training level, but current evidence remains inconclusive. Additionally, this study had a lower training volume (two sessions per week for 15 min over four weeks), which was shorter than most studies reporting significant improvements. More research is needed to compare training volume effects across different populations.

In addition, Zacharakis et al. (2020) reported that static balance significantly improved in young males but not in young females. However, few studies have directly compared balance training outcomes across genders in basketball players. More research is needed to explore potential differences between males and females in response to BT, particularly considering developmental, neuromuscular, and anthropometric factors [60].

Effect of BT on power

Power is crucial for vertical jump performance, crucial in basketball for activities like rebounding, blocking shots, and executing dunks [61]. Five studies reviewed revealed that BT significantly enhanced CMJ and VJ but had no impact on the triple hop distance test and 30-s maximal performance jump test. These results align with a previous systematic review that also highlighted conflicting findings regarding the impact of BT on jumping performance [17]. Balance exercises employed in the studies, such as Swiss ball training and slackline training, enhance neuromuscular efficiency by demanding precise control of muscle activation and synchronization across core and lower extremity muscle groups [62, 63]. This improved neuromuscular coordination can enhance the efficacy of motor unit recruitment during explosive movements like CMJ and VJ. Furthermore, in studies where BT programs incorporated dot and hexagon drills [43], these exercises contributed to balance enhancement by requiring continuous postural adjustments during rapid, repetitive movements. These drills challenge reactive strength and the stretch-shortening cycle (SSC), both of which are crucial for CMJ and VJ performance [64].

However, some studies did not show significant results in power. Specifically, Santos et al. (2016) implemented a BT program with a total training load of approximately 90 to 162 min over six weeks (5–9 min per session, three times per week). This study reported no significant improvement in the 30-second maximal performance jump test, an assessment that involves repeated high-intensity efforts and engages anaerobic energy systems along with muscular endurance demands [51]. Similarly, the power-centered task of the triple hop distance, requiring significant explosive force generation in the lower limbs, did not witness notable enhancements as Panwar & Narwal (2014) applied wobble board training as BT, focusing on stability and control rather than developing the muscular strength or explosive power crucial for significant propulsive forces [47]. Therefore, there is currently limited evidence comparing different BT training volumes and modalities in relation to power performance, highlighting the need for further research to determine optimal BT parameters for improving power in basketball players.

Effect of BT on agility

Agility is essential for excelling in basketball, influencing all facets of the game from offense to defense, transitions, and rebounding [65]. It empowers players to react quickly, execute movements precisely, and maintain control under pressure, making it a crucial factor in basketball performance. The conflicting results of BT on agility align with a previous review [17]. The hexagon test and MZZDT showed improvements in two incorporated studies. Neuromuscular coordination was enhanced by BT through ladder training and dot drills, enhancing the body's capacity to perform rapid and controlled movements, crucial for agility assessments like the hexagon test [66].

The Y reactive agility test did not improve perhaps due to the high baseline level of the participants and the low training volume, as previously mentioned [53]. The maneuver running test did not show improvement potentially because the participants, at just 13 years old, were likely experiencing the adolescent growth spurt phase, characterized by rapid physical changes such as increased height and limb length [67]. These changes could temporarily affect coordination, balance, and movement efficiency, making it challenging to enhance agility or change of direction through training.

Effect of BT on stability

Stability enables players to sustain proper body alignment and control during activities like dribbling, shooting, and defending [68]. In the current review, only one included study explored the impact of BT on stability, showing improvement in the closed kinetic chain upper extremity stability test [48], which heavily relies on upper body strength and shoulder stability to sustain the push-up position while in dynamic motion. Prior reviews also endorse BT as a valuable approach for boosting stability for injury prevention and athletic performance [69]. Fisek & Agopyan (2021) employed BOSU balance disc exercises, delta balance ball exercises, and trampoline exercises in the balance regimen. The instability induced by these exercises challenges the core to enhance stabilization, and exercises on these unstable surfaces enhance the ability to manage rotational forces [70, 71], thereby reducing swaying during alternating hand taps in the assessment. Nonetheless, existing evidence is inadequate to provide conclusive insights into the impact of BT on stability. Further rigorously designed research is necessary to elucidate the relationship between BT and agility.

Effect of BT on basketball performance

The included studies utilized various tools and exercises targeting physical, neuromuscular, and sport-specific factors that collectively improved basketball shooting performance, which necessitates efficient force transfer from the lower body through the core to the upper body [72–74]. For example, exercises such as lunges and single-leg hops combined with shooting focus on core strength and balance during dynamic conditions [49], and Hamdan (2023) utilized tools like bosu balls and fit balls to augment stability and reduce unnecessary body sway during shooting. Enhancing core stability, dynamic balance, proprioception, neuromuscular coordination, and strength ensures better control, precision, and consistency in shooting mechanics, even under dynamic and unstable conditions [72, 75]. Each study incorporated elements of instability, dynamic movement, and sport-specific tasks, making the training highly transferable to basketball performance.

With regard to passing performance, BT strengthens the core and stabilizing muscles, enabling players to generate controlled power during passes and maintain proper posture and alignment when passing under dynamic or unstable conditions [76, 77]. Passing relies on stabilizing muscles in the shoulder and upper body to control the direction, speed, and power of the pass [78, 79]. BT strengthens these stabilizers by challenging them on unstable surfaces [80]. For instance, Fisek & Agopyan (2021) utilized balance discs and delta balls on unstable surfaces to challenge the core, enhancing stability during passing. Nikolaos et al. (2012) employed BOSU balls and TOGU balls to engage core muscles, improving the stability required for accurate and controlled passes.

Regarding dribbling performance, Hamdan (2023) demonstrated the positive effect of BT on various dribbling skills. Dribbling necessitates a strong and stable core to maintain control of the ball while maneuvering through defenders or obstacles [81]. Balance training on unstable surfaces (e.g., BOSU balls, cushion balls) strengthens the core muscles, improving trunk stability [80]. However, unstable surfaces (e.g., cylindrical plank, sponge mattress) challenge proprioception, compelling the athlete to continuously adjust and fine-tune body movements [80]. The enhanced proprioception enables players to better control their body while dribbling, enhancing precision and adaptability during zigzag or quick dribbling drills.

In summary, enhanced balance through BT directly contributes to improved basketball-specific motor skills. For instance, improved dynamic stability helps shooters maintain correct body posture during the jump-shot motion [82], reducing unnecessary sway and leading to increased shooting accuracy. Similarly, improved postural control enables athletes to pass accurately even under defensive pressure [83], enhancing passing precision. Furthermore, dribbling benefits from better body control and reduced instability [84], allowing players to execute rapid directional changes with greater effectiveness. The reactive and dynamic nature of basketball requires players to integrate sensory information rapidly to make effective game-time decisions [85]. BT enhances sensorimotor integration [86], allowing athletes to better adjust their posture during the game, facilitating quicker transitions between movements, such as rapidly changing directions or responding defensively to opponent actions. Future research could further examine how BT specifically influences decision-making and anticipatory control under game-like conditions to optimize training prescriptions.

Nevertheless, Zacharakis et al. (2020) reported that BT did not significantly enhance dribbling, defensive sliding, and lay-up tests in the experimental male group and fast shooting and dribbling tests in the experimental female group. However, few studies have directly examined gender differences in BT effectiveness for basketball performance, making it difficult to draw definitive conclusions. While anthropometric and neuromuscular factors may contribute to variations in training outcomes, current evidence remains inconclusive. Future studies should investigate how sex, age, and skill level influence BT adaptations in basketball players to better understand these inconsistencies.

Limitations

Several limitations need to be acknowledged in this review. Firstly, some studies lacked detailed information on the frequency, duration, or seasonal timing of the BT programs, impacting the ability to draw consistent conclusions about optimal training protocols. Secondly, due to the limited number of studies, subgroup analyses based on factors such as age, sex, or playing level could not be performed. These variables are likely to influence the effectiveness of BT, as younger or less experienced players may respond differently compared to seasoned athletes. Thirdly, the heterogeneity in assessment tools and outcome measures used in the included studies hindered direct comparisons. Although many studies reported significant improvements, the diverse tests used to assess balance, power, and basketball performance may restrict the generalizability of the findings.

Conclusion

This review highlights the role of BT in improving balance, agility, stability, and basketball-specific skills. While several studies demonstrated positive effects, some assessments, such as the balance error scoring system, triple hop distance, and 30-second maximal performance jump test, did not show significant improvements. The variability in training protocols across studies, particularly in intensity, duration, and total training volume, makes it challenging to establish an optimal BT program for basketball players. Therefore, due to the lack of direct comparisons, further research is needed to determine the optimal BT parameters, including the appropriate balance between intensity and volume. Additionally, potential differences in BT responses between genders, playing levels, and age groups remain underexplored. Future studies should systematically investigate these variables to establish evidence-based recommendations for BT in basketball players. Overall, BT presents a promising strategy for enhancing performance-related attributes, but more rigorously controlled studies are required to refine training guidelines and maximize its effectiveness in basketball-specific contexts.

Implications

This systematic review provides both theoretical and practical implications for balance training (BT) in basketball. Theoretically, it contributes to the growing body of research by highlighting BT's role in improving balance, agility, stability, and skill-related performance while identifying gaps in training protocols, particularly in duration, frequency, and intensity. The inconsistent findings in certain performance tests suggest the need for further research on BT's impact on power and its effectiveness across different ages, genders, and playing levels. Practically, BT should be integrated into basketball training programs to enhance movement efficiency, injury prevention, and game performance. Sport-specific BT exercises, such as balance-enhanced dribbling and single-leg stance shooting, can help bridge the gap between balance improvements and basketball skill execution. Future research should focus on establishing optimal BT parameters and tailoring interventions to different player levels to maximize its benefits.

Supplementary Information

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Supplementary Material 1

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Author contributions
S.C. and S.K.G. conducted the literature search and study selection. S.C. initially screened titles and abstracts, followed by a thorough independent review of potentially eligible studies by both L.G. and J.L. Any disagreements regarding study inclusion were resolved through arbitration by J.L. N.C. carried out the study quality assessment. Z.W. and S.C. wrote the main manuscript text. All authors contributed to the manuscript's revision and have read and approved the final published version.

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References

1. Saheb HFA, Malih FA, Demirci N. The impact of a High-Fitness program on developing performance endurance for players of the basketball skills challenge competition. Mod Sport. 2024;23(1).
2. Cao S, et al. The effects of functional training on physical fitness and skill-related performance among basketball players: a systematic review. Front Physiol. 2024;15:1391394.
3. Комоцька ОС, Сушко РО. Modern approaches for the physical training of young female basketball players. Teorìâ Ta Metodika Fizičnogo Vihovannâ, 2022;(2):260–7.
4. Koryahin V, et al. The main aspects of the implementation of technical and physical training of basketball players. J Phys Educ Sport. 2019;19:358–62.
5. Arslan E, et al. Effects of small-sided games training versus high-intensity interval training approaches in young basketball players. Int J Environ Res Public Health. 2022;19(5):2931.
6. Yaggie JA, Campbell BM. Effects of balance training on selected skills. J Strength Conditioning Res. 2006;20(2):422–8.
7. Hrysomallis C. Relationship between balance ability, training and sports injury risk. Sports Med. 2007;37:547–56.
8. Brachman A, et al. Balance training programs in athletes–A systematic review. J Hum Kinetics. 2017;58(1):45–64.
9. Yılmaz O, et al. Effects of proprioceptive training on sports performance: a systematic review. BMC Sports Sci Med Rehabilitation. 2024;16(1):149.
10. Wang H, et al. Correlation among proprioception, muscle strength, and balance. J Phys Therapy Sci. 2016;28(12):3468–72.
11. Kümmel J, et al. Specificity of balance training in healthy individuals: a systematic review and meta-analysis. Sports Med. 2016;46:1261–71.
12. Sturnieks DL. Biomechanics of balance and falling. Falls in older people: risk factors, strategies for prevention and implications for practice. 2021. p. 105.
13. Neptune RR, Vistamehr A. Dynamic balance during human movement: measurement and control mechanisms. J Biomech Eng. 2019;141(7):070801.
14. Han J, et al. The role of ankle proprioception for balance control in relation to sports performance and injury. Biomed Res Int. 2015;2015(1):842804.
15. Ogard WK. Proprioception in sports medicine and athletic conditioning. Strength Conditioning J. 2011;33(3):111–8.
16. Lackner JR, DiZio P. Vestibular, proprioceptive, and haptic contributions to Spatial orientation. Ann Rev Psychol. 2005;56(1):115–47.
17. Zech A, et al. Balance training for neuromuscular control and performance enhancement: a systematic review. J Athl Train. 2010;45(4):392–403.
18. Wiesmeier IK, et al. Balance training enhances vestibular function and reduces overactive proprioceptive feedback in elderly. Front Aging Neurosci. 2017;9:273.
19. Hobbs ML. Dynamic balance and basketball playing ability. 2008.
20. Curtolo M, et al. Balance and postural control in basketball players. Fisioterapia Em Movimento. 2017;30:319–28.
21. Cadore EL, et al. Effects of different exercise interventions on risk of falls, gait ability, and balance in physically frail older adults: a systematic review. Rejuven Res. 2013;16(2):105–14.

22. Taylor JB, Hegedus EJ, Ford KR. Biomechanics of lower extremity movements and injury in basketball. Basketb Sports Med Sci. 2020;37–51.
23. Hamdan AY. The effect of balance training on improving shooting skills and the basketball debate among the students of the faculty of physical education and sports. Volume 18. Revista Iberoamericana de Psicologia del Ejercicio y el Deporte; 2023. pp. 38–47. 1.
24. Lee AC, Sankaravel M, Chen ZX. The effectiveness of six-week balance training with perturbation intervention in enhancing dynamic balance of basketball players. Phys Educ Theory Methodol. 2023;23(1):21–7.
25. Gioftsidou A, et al. Balance training programs for soccer injuries prevention. J Hum Sport Exerc. 2012;7(3):639–47.
26. Cerrah AO, et al. Effects of functional balance training on static and dynamic balance performance of adolescent soccer players. Int J Sport Exerc Train Sciences-IJSETS. 2016;2(2):73–81.
27. Sebastia-Amat S, et al. The effect of balance and sand training on postural control in elite beach volleyball players. Int J Environ Res Public Health. 2020;17(23):8981.
28. Gadre HV, et al. Effect of dynamic balance training on agility in adolescent volleyball players. J Clin Diagn Res. 2019;13(11).
29. Malwanage KT, Senadheera VV, Dassanayake TL. Effect of balance training on footwork performance in badminton: an interventional study. PLoS ONE. 2022;17(11):e0277775.
30. Lu Z, et al. The effect of 6-week combined balance and plyometric training on dynamic balance and quickness performance of elite badminton players. Int J Environ Res Public Health. 2022;19(3):1605.
31. Gebel A, et al. Effects and dose–response relationship of balance training on balance performance in youth: a systematic review and meta-analysis. Sports Med. 2018;48:2067–89.
32. Bellows R, Wong CK. The effect of bracing and balance training on ankle sprain incidence among athletes: a systematic review with meta-analysis. Int J Sports Phys Therapy. 2018;13(3):379.
33. Page MJ, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021;372.
34. Narducci E, et al. The clinical utility of functional performance tests within one-year post-acl reconstruction: a systematic review. Int J Sports Phys Therapy. 2011;6(4):333.
35. Kmet L. Standard quality assessment criteria for evaluating primary research papers from a variety of fields. Alberta Heritage Foundation for Medical Research Edmonton; 2004.
36. Harrer M, et al. Doing meta-analysis with R: A hands-on guide. Chapman and Hall/CRC; 2021.
37. Deeks JJ, et al. Analysing data and undertaking meta-analyses. Cochrane handbook for systematic reviews of interventions. 2019. pp. 241–284.
38. Akers J, Aguiar-Ibáñez R, Baba-Akbari A. Systematic reviews: CRD's guidance for undertaking reviews in health care. University of York; 2009.
39. Zhu J. Influences of balance training on shooting quality in basketball players. Influencias del entrenamiento de equilibrio sobre la calidad del lanzamiento en jugadores de baloncesto. 2023;29:1–4.
40. Mahmoud MH. Balance exercises as the basis for developing the level of physical and skill performance in basketball young players. World J Sport Sci. 2011;4(2):172–8.
41. Sharath U, et al. A study on effect of wobble board balance training program on static balance, dynamic balance, triple hop distance and vertical jump height in basketball athletes. Int J Phys Educ Sports Health. 2020;7(6):163–9.
42. Lin G. Balance training and physical ability of basketball players. Revista Brasileira de Medicina do Esporte; 2023. p. 29.
43. Alhawary R. The effect of dynamic balance exercises on certain kinematic variables and jump shoot accuracy among female basketball players. J Phys Educ Health. 2019;8(14):41–8.
44. Yeole P, Pawar S. Comparison of sports specific balance training programs in improving balance and agility in basketball players. 2019.
45. Nikolaos K, et al. The effect of a balance and proprioception training program on amateur basketball players' passing skills. J Phys Educ Sport. 2012;12(3):316–23.
46. Boccolini G, et al. Using balance training to improve the performance of youth basketball players. Sport Sci Health. 2013;9(2):37–42.
47. Panwar N, et al. Effect of wobble board balance training program on static balance, dynamic balance & triple hop distance in male collegiate basketball athlete. Int J Physiotherapy Res. 2014;2(4):657–2.
48. Fisek T, Agopyan A. Effects of six weeks of stable versus unstable multidimensional surfaces balance training on passing skills and balance performance in young male basketball players. J Men's Health. 2021;17(4):264–77.
49. Boonsom N, Bungmark W. Enhancing basketball jump shot performance and dynamic balance in male basketball players through balance shooting training. J Phys Educ Sport. 2024;24(1):187–95.
50. Domeika A, et al. Effects of an 8-week basketball-specific proprioceptive training with a single-plane instability balance platform. Technol Health Care. 2020.
51. Santos L, et al. Effects of slackline training on postural control, jump performance, and myoelectrical activity in female basketball players. J Strength Conditioning Res. 2016;30(3):653–64.
52. Zacharakis ED, et al. Effect of balance and proprioceptive training on balancing and technical skills in 13-14-year-old youth basketball players. J Phys Educ Sport. 2020;20(5):2487–500.
53. Lee J, et al. Plyometrics or balance training effects on lower body power, balance and reactive agility in collegiate basketball athletes: A randomized control trial. Spor Hekimligi Dergisi/Turkish J Sports Med. 2021;56(1):5–12.
54. Gebel A, et al. Effects of balance training on physical fitness in youth and young athletes: a narrative review. Strength Conditioning J. 2020;42(6):35–44.
55. Lee AC, et al. Development of balance training program to improve balance control among Malaysian sports schools athletes. Pedagogy Phys Cult Sports. 2022;26(3):174–81.
56. Melong C, Keats MR. Comparing the effects of a novel and a traditional proprioceptive balance training program on activity adherence and balance control in a healthy university population: a preliminary study. GAMES HEALTH: Res Dev Clin Appl. 2013;2(5):308–12.
57. Giboin L-S, Gruber M, Kramer A. Three months of slackline training elicit only task-specific improvements in balance performance. PLoS ONE. 2018;13(11):e0207542.
58. Burcal CJ, et al. Predicting dynamic balance improvements following 4-weeks of balance training in chronic ankle instability patients. J Sci Med Sport. 2019;22(5):538–43.
59. Rozzi SL, et al. Balance training for persons with functionally unstable ankles. J Orthop Sports Phys Therapy. 1999;29(8):478–86.
60. Nolan L, Grigorenko A, Thorstensson A. Balance control: sex and age differences in 9-to 16-year-olds. Dev Med Child Neurol. 2005;47(7):449–54.
61. Aksović N, et al. Explosive power in basketball players. Facta Univ Ser Phys Educ Sport. 2020;1:119–34.
62. Stanton R, Reaburn PR, Humphries B. The effect of short-term Swiss ball training on core stability and running economy. J Strength Conditioning Res. 2004;18(3):522–8.
63. Granacher U, et al. Slackline training for balance and strength promotion. Int J Sports Med. 2010;31(10):717–23.
64. Pratama RS, et al. The impact of hexagon drill on the agility of junior Men's tennis players. Jurnal Keolahragaan. 2023;11(1):33–40.
65. Sekulic D, et al. Evaluation of basketball-specific agility: applicability of Preplanned and nonplanned agility performances for differentiating playing positions and playing levels. J Strength Conditioning Res. 2017;31(8):2278–88.
66. Filipa A, et al. Neuromuscular training improves performance on the star excursion balance test in young female athletes. J Orthop Sports Phys Therapy. 2010;40(9):551–8.
67. Chulani VL, Gordon LP. Adolescent growth and development. Prim Care. 2014;41(3):465–487.
68. Notarnicola A, et al. Effects of training on postural stability in young basketball players. Muscles Ligaments Tendons J. 2016;5(4):310.
69. DiStefano LJ, Clark MA, Padua DA. Evidence supporting balance training in healthy individuals: a systemic review. J Strength Conditioning Res. 2009;23(9):2718–31.
70. Sawant RA, et al. Effectiveness of Bosu ball exercises versus thera band exercises on core stabilization and balance performance. Indian J Forensic Med Toxicol. 2020;14(2):200–6.
71. Karakollukçu M, et al. Effects of mini trampoline exercise on male gymnasts' physiological parameters: a pilot study. J Sports Med Phys Fit. 2015;55(7–8):730–4.
72. Hassan AK, et al. The impact of core complex training on some basketball-related aspects of physical strength and shooting performance. Eur J Invest Health Psychol Educ. 2023;13(9):1624–44.
73. Xue P. The effect of core strength training on basketball players' shooting percentage. Mol Cell Biomech. 2024;21(2):452–452.
74. Arora C, Singh P, Varghese V. Biomechanics of core musculature on upper extremity performance in basketball players. J Bodyw Mov Ther. 2021;27:127–33.
75. Behm DG, et al. The use of instability to train the core musculature. Appl Physiol Nutr Metab. 2010;35(1):91–108.

76. Luo S, et al. Effect of core training on athletic and skill performance of basketball players: A systematic review. PLoS ONE. 2023;18(6):e0287379.
77. Ramadhani SI, Wahyuni W, Wijianto W. The effect of stretching lower extremity and core stability on the dynamic balance of ums basketball player: a case study. In: Academic Physiotherapy Conference Proceeding. 2021.
78. Sachanidi M, et al. Passing efficacy of young basketball players: test or observation? Int J Perform Anal Sport. 2013;13(2):403–12.
79. Maimón AQ, Courel-Ibáñez J, Ruíz FJR. The basketball pass: A systematic review. J Hum Kinetics. 2020;71:275.
80. de Silva B. Effect of wobble board training on movement strategies to maintain equilibrium on unstable surfaces. Hum Mov Sci. 2018;58:231–8.
81. Ferioli D, et al. Combined effect of number of players and dribbling on game-based-drill demands in basketball. Int J Sports Physiol Perform. 2020;15(6):825–32.
82. Rasool J, George K. The impact of single-leg dynamic balance training on dynamic stability. Phys Ther Sport. 2007;8(4):177–84.
83. Kollmitzer J, et al. Effects of back extensor strength training versus balance training on postural control. Med Sci Sports Exerc. 2000;32(10):1770–6.
84. Mollà-Casanova S, Inglés M, Serra-Añó P. Effects of balance training on functionality, ankle instability, and dynamic balance outcomes in people with chronic ankle instability: systematic review and meta-analysis. Clin Rehabil. 2021;35(12):1694–709.
85. Ostojic SM, Mazic S, Dikic N. Profiling in basketball: physical and physiological characteristics of elite players. J Strength Conditioning Res. 2006;20(4):740–4.
86. Sefton JM, et al. Six weeks of balance training improves sensorimotor function in individuals with chronic ankle instability. J Orthop Sports Phys Therapy. 2011;41(2):81–9.

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