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Effect of neuromotor exercises on balance in basketball players: a systematic review with meta-analysis

Efeito de exercícios neuromotores no equilíbrio em jogadores de basquete: uma revisão sistemática com metanálise

Efecto de los ejercicios neuromotores sobre el equilibrio en jugadores de baloncesto: una revisión sistemática con metanálisis

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Abstract
Aim: the purpose of this review is to evaluate the effect of lower limb neuromotor exercises on static and dynamic balance in basketball players. Methods: the search strategy was carried out in the following databases: Medline/Pubmed, LILACS, Scopus, and PEDRO. Certainty of evidence was assessed by GRADE for posteromedial, posterolateral, and anterior directions, and composite score of the Star Excursion Balance Test. Results: the initial search identified 520 studies. Of them, six studies were included in this review, and three of them were included in the meta-analysis (n = 64). GRADE evaluation indicated low level of certainty of evidence for posteromedial (MD = 4.92%; 95% CI = -1.44 to 11.29; P = 0.13; I^2 = 55%), posterolateral (MD = 6.08%; 95% CI = 2.76 to 9.40; P = 0.0003; I^2 = 19%) and anterior (MD = 4.87%; 95% CI: 2.84 to 6.89; p<0.00001; I^2= 0%) directions. Very low level of certainty of evidence was found for composite score (MD = 6.42%; 95% CI: 5.03 to 7.82 P < 0.00001; I^2 = 1%). Conclusions: neuromotor exercises improve dynamic balance in basketball players. Although, the certainty of evidence is still very low. So, our data should be cautiously interpreted.
Keywords: Lower extremity; Plyometric Exercise; Postural balance; Proprioception.

Resumo

Objetivo: o objetivo desta revisão é avaliar o efeito de exercícios neuromotores de membros inferiores no equilíbrio estático e dinâmico em jogadores de basquete. Métodos: a estratégia de busca foi realizada nas seguintes bases de dados: Medline/Pubmed, LILACS, Scopus e PEDRO. O nivel de certeza da evidência foi avaliado pelo GRADE para as direções posteromedial, posterolateral e anterior e valor composto do Star Excursion Balance Test. Resultados: a busca inicial identificou 520 estudos. Destes, seis estudos foram incluídos nesta revisão, e três deles foram incluídos na meta-análise (n = 64). A avaliação através do GRADE indicou baixo nível de certeza da evidência para posteromedial (MD = 4,92%; IC 95% = -1,44 a 11,29; P = 0,13; I^2 = 55%), posterolateral (MD = 6,08%; IC 95% = 2,76 a 9,40; P = 0,0003; I^2 = 19%) e anterior (MD = 4,87%; IC 95%: 2,84 a 6,89; p<0,00001; I^2= 0%). Muito baixo nível de certeza de evidência foi encontrado para o valor composto (MD = 6,42%; IC 95%: 5,03 a 7,82 P < 0,00001; I^2 = 1%). Conclusões: Exercícios neuromotores melhoram o equilíbrio dinâmico em jogadores de basquete. Embora, a certeza da evidência ainda seja muito baixa. Portanto, nossos dados devem ser interpretados com cautela.

Palavras-chave: Extremidade inferior; Exercício pliométrico; Equilíbrio postural; Propriocepção.

Resumen

Objetivo: el propósito de esta revisión es evaluar el efecto de los ejercicios neuromotores de miembros inferiores sobre el equilibrio estático y dinámico en jugadores de baloncesto. Métodos: la estrategia de búsqueda se realizó en las siguientes bases de datos: Medline/Pubmed, LILACS, Scopus y PEDRO. La certeza de la evidencia se evaluó mediante GRADE para las direcciones posteromedial, posterolateral, anterior y valor compuesto del Star Excursion Balance Test. Resultados: la búsqueda inicial identificó 520 estudios. De ellos, seis estudios se incluyeron en esta revisión y tres de ellos se incluyeron en el metanálisis (n = 64). La evaluación GRADE indicó un nivel bajo de certeza de la evidencia para posteromedial (DM = 4,92 %; IC 95 % = -1,44 hasta 11,29; P = 0,13; I^2 = 55%), posterolateral (DM = 6,08 %; IC 95 % = 2,76 hasta 9,40); P = 0,0003; I^2 = 19%) y anterior (DM = 4,87%; IC 95%: 2,84 hasta 6,89; p<0,00001; I^2= 0%) direcciones. Se encontró un nivel muy bajo de certeza de la evidencia para valor compuesto (DM = 6,42 %; IC 95 %: 5,03 hasta 7,82 P < 0,00001; I^2 = 1 %). Conclusiones: Exercícios neuromotores melhoram o equilíbrio dinâmico em jogadores de basquete. Embora, a certeza da evidência ainda seja muito baixa. Portanto, nossos dados devem ser interpretados com cautela.

Palabras clave: Extremidad inferior; Ejercicio pliométrico; Equilibrio postural; Propiocepción.

1. Introduction

Basketball is one of the most popular sports worldwide. Around 11% of the world population practices this modality (Harmer, 2005), and approximately seven to ten out of 1000 basketball athletes report injuries (Taylor et al., 2015). Evidence supports the inclusion of balance exercises to regular training of professional and amateur basketball players to improve motor skills and reduce injury frequency (Hrysomallis, 2007; McGuine et al., 2000; TA. McGuine & Keene, 2017).

Neuromotor exercises have been performed more frequently in basketball (Brachman et al., 2017). Neuromotor exercises are described by the American College of Sports Medicine as training that incorporates various motor activities, such as balance, coordination, gait, agility, and proprioceptive training. These exercises improve balance, agility, muscle strength, and reduce fall risk in older adults (Garber et al., 2011). However, few studies have investigated the benefits of neuromotor exercises in young adults, although some authors suggest that they may reduce injuries in athletes (Chodzko-Zajko et al., 1998).

Studies with male athletes of various sport modalities correlated balance with agility during sports gestures and demonstrated that balance control is essential for performance (Han et al., 2015; Notarnicola et al., 2015; Sekulic et al., 2013). In addition, a study with adolescent basketball players observed that the addition of neuromotor exercises (balance and plyometric training combined) to regular training was found to be a safe, feasible intervention and also was able to improve the athletes' balance and agility (Bouteraa et al., 2020). However, the effectiveness of neuromotor exercises in basketball is still unknown in adults.

Besides improving sports performance, neuromotor exercises have also been adopted to prevent lower limb injuries (Hrysomallis, 2007). Although some studies show gains in postural control and risk of injury for athletes who implement these exercises, most studies fail to analyze different sports modalities (Caldemeyer et al., 2020; Fitzgerald et al., 2000; Williams et al., 2016). Also, a study that focused on basketball players showed that a neuromotor exercise program with bodyweight effectively improved awareness of static and dynamic joint positioning and postural control (Benis et al., 2016).

Although some evidence suggests the use of neuromotor exercises for athletes, literature lacks systematic reviews with meta-analysis regarding the effects of lower limb neuromotor exercises on balance in basketball athletes. Therefore, this systematic review aimed to review the available evidence regarding the effect of lower limb neuromotor exercises on static and dynamic balance in basketball players compared to other types of exercises.

2. Methodology

This systematic review was registered on PROSPERO (CRD42020177783) and described according to the Preferred Reporting terms for Systematic Reviews and Meta-Analyses (PRISMA) checklist (Liberati et al., 2009). Our guiding question was "Do neuromotor exercises improve balance in adult basketball players compared to other interventions or control group?”. Inclusion and exclusion criteria followed the PICO framework (population, intervention, comparison, outcome, and type of study), as described below:

Population: studies investigating professional or amateur basketball players of both genders, aged between 18 and 50 years (studies that compared athletes with non-athletes and studies with athletes from various sport modalities were excluded).

Intervention: studies that used neuromotor exercises focused on lower limbs were included. We considered neuromotor: plyometric exercises, neuromuscular exercises, training performed on stable and unstable surfaces, proprioceptive training, functional training, and balance training.

Comparison: any treatment other than neuromotor exercise or no intervention (control).

Outcomes: the primary outcome was dynamic and static balance assessed using clinical tests (e.g., Romberg, one-leg balance test, star excursion balance test) or instrumental measurements of balance (e.g., force platform, balance platform, and stabilometry). The secondary outcome was the presence of adverse effects to neuromotor exercises (studies that did not assess balance as primary or secondary outcome were excluded).

Study design: randomized controlled trials or quasi-randomized trials.

2.1 Search Strategy

The search strategy was based on the Cochrane handbook for systematic reviews of interventions (J. P. Higgins et al., 2019). Two authors (J.F. and V.O.) performed the search strategy independently. Medline/Pubmed, LILACS, Scopus, and PEDro electronic databases were searched using the boolean operator AND on December 2021. The search was conducted using Medical Subject Headings (MeSH) and Health Sciences Descriptors (DeCS) and keywords. Details of the search strategy are shown in Table 1. The list of references from the selected articles were inspected for additional eligible studies. No limits on year of publication or language were used.

Table 1. Search strategies in each database to identify the effectiveness of neuromotor exercises on balance in basketball players.

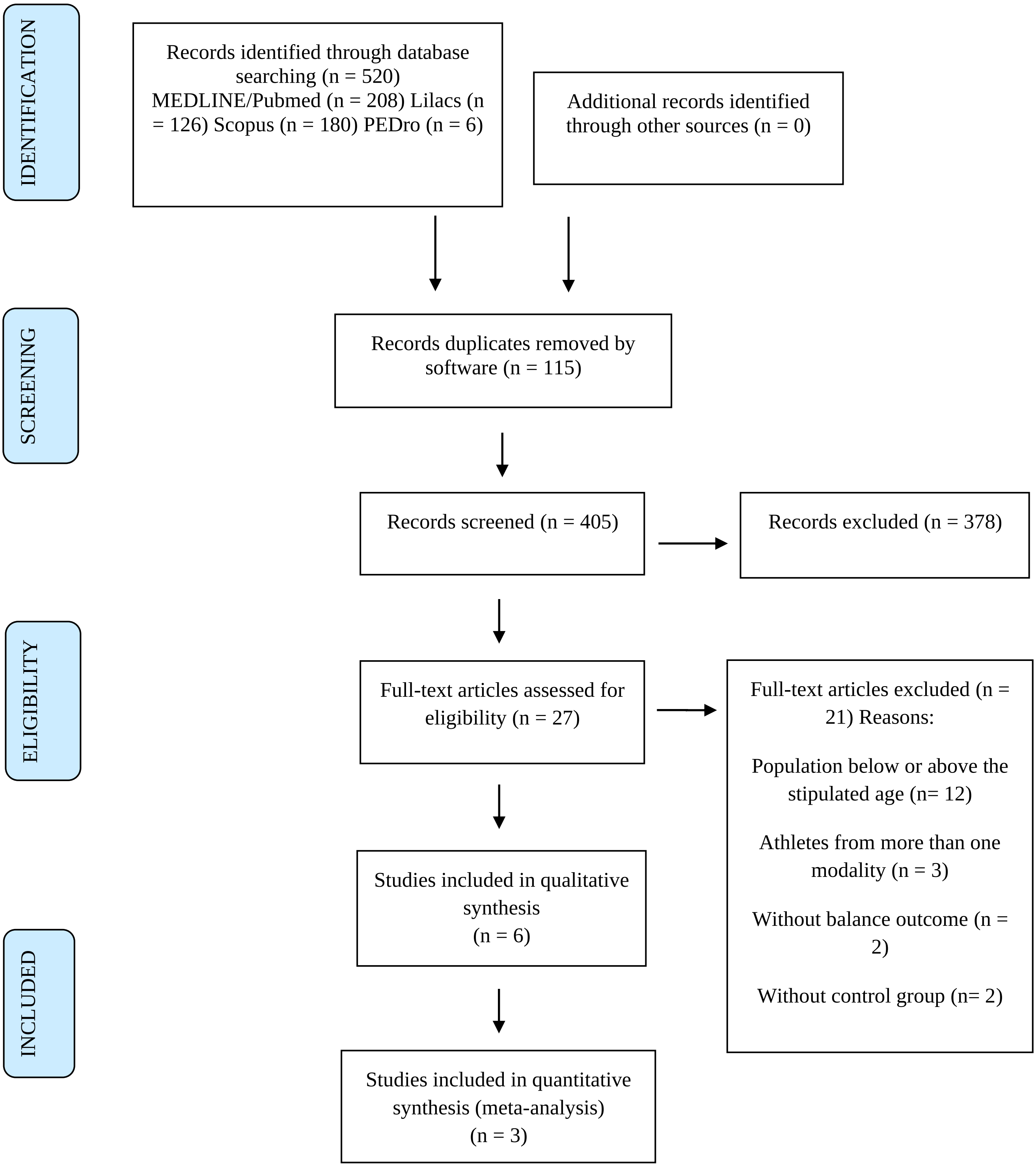
Databases	**Descriptors used**	**Findings**
MEDLINE/Pubmed	#1 Basketball AND Postural Balance #2 Basketball AND Postural Balance AND lower limb stability #3 Basketball AND Postural Balance AND Proprioception	104 15 89 Total= 208
Lilacs	#1 Basketball AND Postural Balance #2 Basketball AND Postural Balance AND lower limb stability #3 Basketball AND Postural Balance AND Proprioception	108 5 13 Total= 126
Scopus	#1 Basketball AND Postural Balance #2 Basketball AND Postural Balance AND lower limb stability #3 Basketball AND Postural Balance AND Proprioception	116 46 18 Total= 180
PEDro	#1 Basketball* Postural Balance #2 Basketball* lower limb stability #3 Basketball AND Proprioception	2 3 1 Total= 6

Source: Authors.

2.2 Study Selection

Selected articles were organized in Mendeley® software, and duplicates were removed. Initially, titles and abstracts were independently evaluated by two authors (J.F. and V.O.). Articles that met inclusion criteria or eligibility was not clear based on the abstract, were selected for full-text reading. The final selection was decided by consensus between both authors (J.F. and V.O.). Study selection process is described in a flowchart based on PRISMA (Figure 1).

Figure 1. Flowchart of selection steps of articles according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).



Source: Authors.

2.3 Risk of Bias Assessment

The Cochrane risk of bias (RoB 2) tool was used to assess the methodological quality of studies (J. P. T. Higgins et al., 2011). This tool covers six domains of bias in randomized trials: randomization process, deviations from intended interventions, missing outcome data, measurement of the outcome, selection of the reported result, and overall. Two authors

(J.F. and A.S.) independently filled out the questions for each domain by checking "yes", "probably yes", "probably not", "no", or "not reported".

An algorithm was generated, and authors classified the risk of bias as high, low, or uncertain. RoB 2 considers a high risk of bias when at least one of the domains is identified as high risk or when multiple domains are classified as uncertain. To be considered uncertain, at least one domain must be identified as uncertain and no domain must be identified as high risk. To be considered low risk of bias, all domains must be identified as low risk (Higgins et al., 2019).

2.4 Assessment of Certainty of Evidence

The Grading of Recommendations Assessment, Development, and Evaluation (GRADE) was used to assess the certainty of evidence and implications for professional practice. Two authors (J.F. and A.S.) independently filled out questions regarding five domains: study design, risk of bias, inconsistency, indirectness and imprecision.

Certainty of evidence was classified as high, moderate, low, or very low. High level indicates that researchers are quite confident that the effect found in their study is close to the true effect. Moderate level indicates that the actual effect is likely to be close to the estimated effect. Low level of certainty indicates that confidence in the estimated effect is limited. Finally, very low level indicates little confidence in the effect (Balshem et al., 2011).

2.5 Meta-Analysis

Meta-analysis was performed using studies that presented similar intervention protocols and balance assessments. Articles that assessed dynamic balance using the traditional or modified Star Excursion Balance Test (SEBT) were selected. SEBT is a reliable measure for identifying deficits in dynamic balance in patients with a variety of lower limb conditions (Gribble et al., 2012).

In traditional SEBT, athlete performs the greatest possible displacement of the lower limb in one-leg support in eight directions. The modified SEBT uses only three directions (anterior, posteromedial, and posterolateral). In addition to directions, it is possible to calculate a composite score (CS). In traditional SEBT, CS is calculated as the average of the eight directions (Goddard & Dickey, 2019). In modified SEBT, CS is calculated by adding the range distances of the three directions, dividing by three times the length of the lower limb, and multiplying by 100 (Plisky et al., 2006, 2009). CS and subgroup analysis were performed for each direction of the modified SEBT. If included articles did not display all the necessary results for this analysis, we contacted the authors. Alternatively, we calculated CS when articles provided the required information to compute it.

Meta-analysis was performed using the Review Manager (RevMan) software (version 5.3; The Nordic Cochrane Centre, Copenhagen, Denmark). The mean difference of displacements was calculated, and a significance level of $P \leq 0.05$ was adopted. Heterogeneity was investigated using the heterogeneity index test (I2). Low heterogeneity was considered when $P \leq 0.05$ and I2 values were up to 30%. I2 values close to 50% indicate moderate heterogeneity, and close to 75% indicate high heterogeneity (J. P. Higgins et al., 2019; J. P. T. Higgins et al., 2019). In cases of heterogeneity between studies, an analysis of the effect of interest was performed using the random-effects model.

3. Results

As shown in Figure 1, the initial search identified 520 studies; however, 115 duplicates were removed. The remaining 405 studies were evaluated by title and abstract, of which 27 were selected for full-text reading. Of the 27 selected articles, six original articles (Asadi, 2013; Asadi et al., 2015; Benis et al., 2016; Bonato et al., 2018; Cherni et al., 2019; Domeika et al., 2020) published between 2013 and 2020 met the eligibility criteria.

Of these six selected articles, five of them used the SEBT to assess dynamic balance and were initially identified as eligible for meta-analysis (Asadi, 2013; Asadi et al., 2015; Benis et al., 2016; Bonato et al., 2018; Domeika et al., 2020). However, two did not present all the necessary data to perform the analysis (Benis et al., 2016; Domeika et al., 2020). One presented an intervention protocol that differed significantly from the other articles; it lasted 24 weeks (four times a week) (Bonato et al., 2018), while the other articles lasted between six and eight weeks (two to three times a week). We could contact the authors of one of the two articles with incomplete data (Benis et al., 2016). Therefore, the meta-analysis included three articles (Asadi, 2013; Asadi et al., 2015; Benis et al., 2016). The characterization of the studies included in this review is described in Table 2.

Table 2. Characteristics of the studies included in the systematic review addressing the effect of neuromotor exercises on the balance of adult basketball players, 2013-2020.

Author, year (country)	Participants (gender, group, number and age)	Intervention Group	Comparison Group	Outcomes (assessment tool)	Results	Adverse effects
Asadi, 2013 (Irã)	Male IG (n=10): 20.2 (SD 1.0) years CG (n=10): 20.1 (SD 1.5) years	Plyometric training (in-season): 55 min, 2x/week, for 6 weeks.	Standard technical and tactical training during the season: 90 min, 3x/week, for 6 weeks.	Dynamic balance (SEBT)	No significant improvement in IG (p>0.05) MD: A = -5.48, AM = 0.22, AL =-6.69, M = 5.31, L = -6.37, P = -4.2, PM = -0.66 and PL = -2.22	There were no adverse effects during the study period in IG or CG
Asadi; Villarreal; Arazi, 2015 (Irã)	Male IG (n=8): 20.1 (SD 0.8) years CG(n=8): 20.5 (SD 0.3) years	Plyometric training (pre-season): 60 min, 2x/week, for 6 weeks.	Pre-season technical and tactical standard training (does not inform time, frequency and duration).	Dynamic balance (SEBT)	↑ significant in all directions of IG compared to CG (p>0.05), except PM and PL. MD: A = -5.48, AM = 0.22, AL =-6.69, M = 5.31, L = -6.37, P = -4.2, PM = -0.66 and PL = -2.22.	There were no adverse effects during the study period in IG or CG
Benis; Bonato; Torre, 2016 (Itália)	Female IG (n=14): 20 (SD 2) years CG (n=14): 20 (SD 1) years	Neuromuscular training (during season): 30 min, 2x/week, for 8 weeks.	Standard technical and tactical training during the season (does not inform time, frequency and duration).	Dynamic balance (modified SEBT)	↑ significant was found in IG compared to CG (p<0.05) in the PM D direction (+4.1%), PM L (+10%), CS R (+7.1%) and CS L (+7.3%).	There were no adverse effects during the study period in IG or CG
Bonato; Benis; Torre, 2018 (Itália)	Female IG (n=86): 20 (SD 2) years CG (n=74): 20 (SD 1) years	Neuromuscular training (during season): 30 min, 4x/week, for 24 weeks.	Standard technical and tactical training during the season (does not inform time, frequency and duration).	Dynamic balance (modified SEBT)	↑ significant was found in IG compared to CG (p<0.05) CS R (+3.7%) and CS L (+2.3%).	93 lower limb injuries were reported during the season: IG = 25; CG = 68
Cherni et al, 2019 (Tunísia)	Female IG (n=13): 20.9 (SD 2.6) years CG (n=12): 21 (SD 3) years	Plyometric training (in-season): 2x/week for 8 weeks (does not inform training time).	Standard technical and tactical training during the season: 5x/week.	Static and dynamic balance (force platform)	Static balance: ↓ length of EO path (p<0.05), with no significant differences in the anteroposterior plane (p>0.05). Dynamic balance (mid-lateral plane): ↓ length of EO path (p<0.05); ↓ surface area and CE velocity (p<0.05)	A quadriceps muscle tearing injury during training (CG) has been reported
Domeika et al, 2020 (Lituânia)	Male IG (n=17) e CG (n=14): 21.3 (SD 0.6) years	Proprioceptive training (does not inform season): 140 min, 3x/week, for 8 weeks.	Standard technical and tactical training (does not inform time, frequency and duration).	Static and dynamic balance (balance platform and modified SEBT)	Static balance: no significant improvement (p>0.05). Dynamic balance: ↑ significant (p<0.05) IG compared to CG for CS R (+6.42%). No significant difference (p>0.05) in CS L	not investigated

n= Number of participants; **IG**= Intervention Group; **CG**= Comparison Group; **SD =** standard deviation**; min**= minutes; **SEBT**= Star Excursion Balance Test; ↑ = Increase; ↓= Reduction; **A**= Anterior; **AM=** Anteromedial; **AL=** Anterolateral; **M=** Medial; **L=** Lateral; **P=** Posterior; **PM=** Posteromedial; **PL=** Posterolateral; **R**= Right; **L**= Left; **CS** = composite score; EO= Eyes open; **CE**= Closed eyes; **LLL**= left lower limb; **RLL**= right lower limb; **MD**= Mean difference. Source: Authors.

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3.1 Risk of bias assessment

Of the six articles included in this review, two were at high risk of bias (Asadi, 2013; Domeika et al., 2020) and four were at moderate risk of bias (Asadi et al., 2015; Benis et al., 2016; Bonato et al., 2018; Cherni et al., 2019). All studies showed flaws in the randomization process, either due to lack of information or because they did not follow good randomization standards (Benis et al., 2016). Methodological limitations of each study and its evaluated components are shown in Figure 2.

Figure 2 Assessing the risk of bias of the studies included in the review using the Cochrane RoB 2 Collaborative Tool, 2013-2020.

YBT = Y Balance Test; **CMJ** = Counter Movement Jump; **SEBT** = Star Excursion Balance Test. Source: Authors.

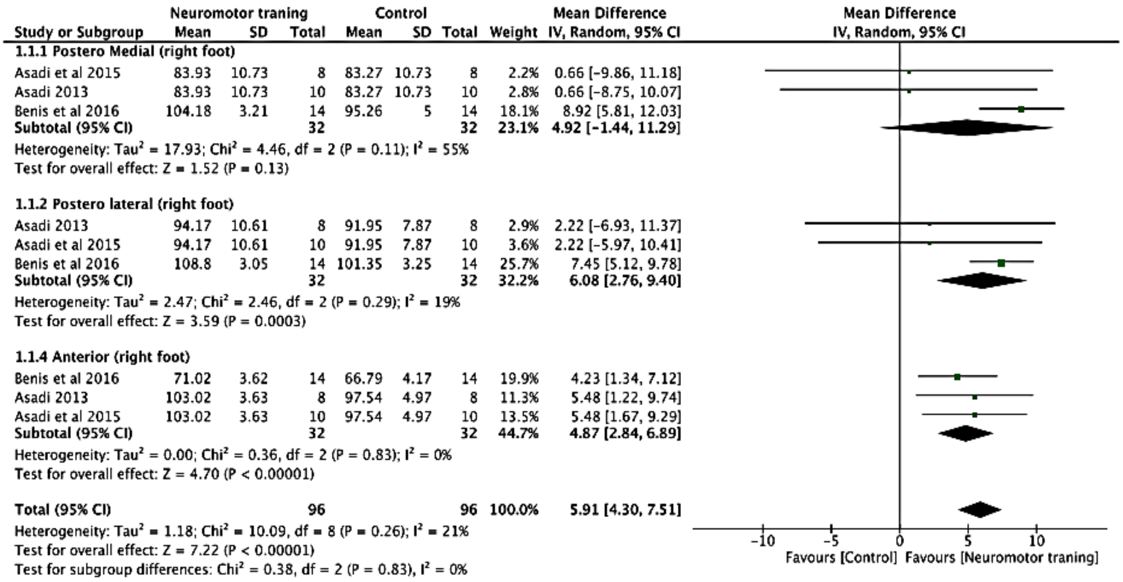
3.2 Balance

The main outcome for this review was balance and its possible changes immediately after the end of neuromotor exercises. Included articles performed plyometric, neuromuscular, and proprioceptive training protocols. This review included 280 adult basketball players, about 76.07% of the total population were female. Balance was assessment using the traditional SEBT (Asadi, 2013; Asadi et al., 2015), modified SEBT (Benis et al., 2016; Bonato et al., 2018; Domeika et al., 2020), or force platform (Cherni et al., 2019; Domeika et al., 2020).

Only one study assessed static balance (Cherni et al., 2019). Of the variables analyzed from the force platform (surface area, path length, and speed), only the “path length with open eyes” variable showed significant change ($P = 0.038$, $d = 0.937$), favoring the experimental group when compared to control.

All articles showed dynamic balance improvement in basketball players after neuromotor exercises compared to control group (Asadi, 2013; Asadi et al., 2015; Benis et al., 2016; Bonato et al., 2018; Cherni et al., 2019; Domeika et al., 2020). However, one of the articles did not show significant balance improvement ($P > 0.05$) (Asadi et al., 2015). Neuromotor training varied regarding intervention duration (between 30 and 140 minutes) (Bonato et al., 2018; Domeika et al., 2020), frequency (two to four times a week) (Asadi, 2013; Bonato et al., 2018), and training exposure time (six to 24 weeks) (Asadi, 2013; Bonato et al., 2018). Further details are described in Table 2. A meta-analysis was performed with the main displacements of the modified SEBT: anterior, posterolateral, and posteromedial (Asadi, 2013; Asadi et al., 2015; Benis et al., 2016) (Figure 3).

Figure 3. Forest plot to identify whether neuromotor exercises alter the displacements of the Anterior, Postero-Lateral, Postero-Medial directions of basketball athletes, 2013-2016.



Source: Authors.

3.2.1 Posteromedial Displacement

The mean difference for posteromedial displacement was 4.92%, with no statistical difference between groups (64 participants; MD = 4.92%; 95% CI = -1.44 to 11.29; random effect; P = 0.13; I2 = 55%) (Figure 3). GRADE evaluation indicated low level of certainty of evidence for posteromedial displacement (Asadi, 2013; Asadi et al., 2015; Benis et al., 2016). Risk of bias, inconsistency and imprecision presented serious limitations (Figure 4).

Figure 4. Level of certainty of evidence assessed by the GRADE system comparing motor control with tactical training in basketball players.

Certainty assessment							№ of patients		Effect		Certainty
№ of studies	**Study design**	**Risk of bias**	**Inconsistency**	**Indirectness**	**Imprecision**	**Other considerations**	**Motor control**	**Tactical training**	**Relative (95% CI)**	**Absolute (95% CI)**	
Motor control (assessed with: Posteromedial (right foot))											
3	Randomised trials	Serious (a)	Serious (b)	Not serious	Serious (c)	All plausible residual confounding would reduce the demonstrated effect	32	32	-	MD = 4.92%; 95% CI = -1.44 to 11.29	⊕⊕◯◯ Low
Motor Control (assessed with: Posterolateral (right foot))											

Certainty assessment							№ of patients		Effect		Certainty
№ of studies	**Study design**	**Risk of bias**	**Inconsistency**	**Indirectness**	**Imprecision**	**Other considerations**	**Motor control**	**Tactical training**	**Relative (95% CI)**	**Absolute (95% CI)**	
3	Randomised trials	Serious (a)	Serious (b)	Not serious	Serious (c)	All plausible residual confounding would reduce the demonstrated effect	32	32	-	MD = 6.08%; 95% CI = 2.76 to 9.40	⊕⊕◯◯ Low
Motor control (assessed with: Anterior (right foot))											
3	Randomised trials	Serious (a)	Serious (b)	Not serious	Serious (c)	All plausible residual confounding would reduce the demonstrated effect	32	32	-	MD = 4.87%; 95% CI: 2.84 to 6.89	⊕⊕◯◯ Low
Motor control (assessed with: composite score)											
5	Randomised trials	Very serious (a)	Serious (d)	Not serious	Serious (e)	None	135	120	-	MD = 6.42%; 95% CI: 5.03 to 7.82 (f)	⊕◯◯◯ Very low

CI: confidence interval; **MD:** mean difference
Explanations: **(a)** One study (Asadi 2013) presented high risk of bias. **(b)** One study (Benis et al 2016) presented difference between groups, while the others studies didn't present. **(c)** $I^2 = 50\%$. **(d)** One Study (Domeika et al) presented results higher than the others studies. **(e)** There is a heterogeneity across studies. **(f)** Mean difference calculated from the following studies: Asadi 2013; Asadi et al. 2015; Benis et al. 2016.

3.2.2 Posterolateral Displacement

Meta-analysis showed that basketball players who performed neuromotor exercises improved posterolateral displacement with a mean difference of 6.08% (64 participants; MD = 6.08%; 95% CI = 2.76 to 9.40; random effect; P = 0.0003; I2 = 19%) (Figure 3). GRADE evaluation showed low level of certainty of evidence for posterolateral displacement (Asadi, 2013; Asadi et al., 2015; Benis et al., 2016). Risk of bias, inconsistency and imprecision presented serious limitations (Figure 4).

3.2.3 Anterior Displacement

The mean difference for anterior displacement was 4.87% (64 participants; MD = 4.87%; 95% CI: 2.84 to 6.89; random effect; P < 0.00001; I2 = 0%) (Figure 3). GRADE evaluation showed a low level of certainty of evidence for anterior displacement (Asadi, 2013; Asadi et al., 2015; Benis et al., 2016). Risk of bias, inconsistency and imprecision presented serious limitations (Figure 4).

3.2.4 Composite Score

The meta-analysis of CS showed that neuromotor exercises improved 6.42% (64 participants; MD = 6.42%; 95% CI:

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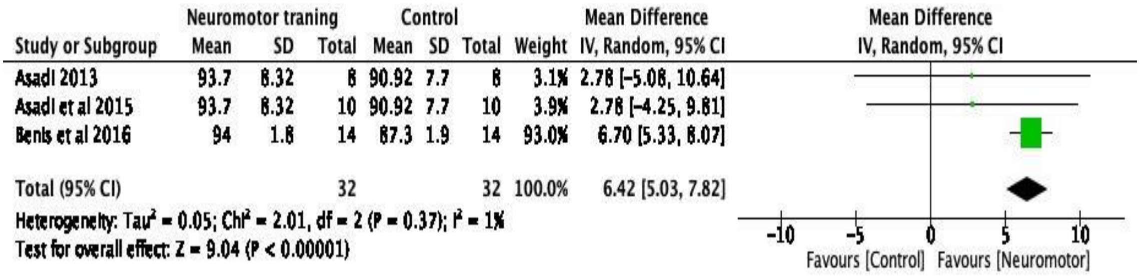
5.03 to 7.82; random effect; P < 0.00001; I2 = 1%) of dynamic balance in basketball players compared to control group (Figure 5). Three studies assessed CS (Benis et al., 2016; Bonato et al., 2018; Domeika et al., 2020). However, two presented data from which the author of this review was able to calculate (Asadi, 2013; Asadi et al., 2015). Therefore, the assessment of the quality of evidence of CS was performed in five studies using GRADE (Asadi, 2013; Asadi et al., 2015; Benis et al., 2016; Bonato et al., 2018; Domeika et al., 2020). Certainty of evidence of CS was classified as very low. Risk of bias had very serious limitations. Inconsistency and imprecision domains had serious limitations (Figure 4).

Figure 5. Forest plot to identify whether neuromotor exercises alter the dynamic balance (composite score) of basketball athletes, 2013-2016.



Source: Authors.

3.3 Static Balance

Two studies assessed static balance (Cherni et al., 2019; Domeika et al., 2020). In Cherni et al. (2019), intervention reduced the path length when athletes were with eyes open. However, postural control of the anterior plane did not differ between groups. Risk of bias of this study was uncertain according to RoB 2 tool. Domeika et al. (2020) found no significant improvement in static balance using a force platform and the risk of bias was high.

3.4 Adverse Effects

Neuromotor exercises and tests seemed to be well tolerated by athletes in three studies (Asadi, 2013; Asadi et al., 2015; Benis et al., 2016). Bonato, Benis, and Torre (2018) observed a total of 93 injuries during basketball season (25 in the intervention group and 98 in the control group). Cherni et al. (2019) excluded one athlete from the control group due to a quadriceps muscle tearing injury. Domeika et al. (2020) did not report any type of adverse effects (Table 2).

4. Discussion

The main finding of this review was that neuromotor exercises during basketball practice improved dynamic balance in basketball players. However, the level of certainty is still very low. Therefore, results must be interpreted with caution.

In the meta-analysis, the posteromedial, posterolateral, and anterior directions had a mean difference of 4.92%, 6.08%, and 4.87%, respectively. The minimum detectable change (MDC), the smallest amount of change outside the instrument's measurement error in a study performed with healthy adults (van Lieshout et al., 2016) for the posteromedial, posterolateral, and anterior directions, was 10.3%, 12.3%, 4.4%, respectively. Thus, only the anterior direction presented results above the MDC among the three directions. This result distinguishes the values obtained from the SEBT test from possible measurement errors. A study conducted on college athletes emphasizes the importance of evaluating asymmetries in the anterior distance reach of SEBT because it may help identify athletes at risk of suffering non-contact knee or ankle injuries (Stiffler et al., 2017).

Meta-analysis showed a mean difference of CS of 6.42% for three studies (Asadi, 2013; Asadi et al., 2015; Benis et al., 2016). Certainty of evidence of CS covered more studies (Asadi, 2013; Asadi et al., 2015; Benis et al., 2016; Bonato et al., 2018; Domeika et al., 2020) and was very low. Risk of bias had very serious limitations due to a study that had a high risk of bias (Asadi, 2013); inconsistency had serious limitations due to a study that showed higher results than the other studies (Domeika et al., 2020); and imprecision presented serious limitations, as there is heterogeneity between studies, thus requiring careful analysis of the CS.

MDC for CS found by van Lieshout et al (2016) is 6.9%, a value slightly above the one found in our review, but within the confidence interval (95% CI: 5.03, 7.82). Thus, dynamic balance of basketball players improved, but not enough to reach MDC. It is worth mentioning that the risk of bias assessed by the RoB 2 tool was high for Asadi (2013) and Domeika et al. (2020). Participants from both studies were aware of their assigned intervention group, and authors did not clearly report information about missing data.

Two studies (Cherni et al., 2019; Domeika et al., 2020) evaluated static balance, and their results do not support the implementation of neuromotor exercises. One of the possible explanations is that exercises used in these studies were focused on dynamic balance training, such as the plyometric exercises (jumping) (Cherni et al., 2019), and exercises on an unstable platform (Domeika et al., 2020). Another factor that may have interfered with the result is that one study did not provide information about the randomization process or allocation (Domeika et al., 2020). Failures in randomization and allocation strategy can generate incomparable groups regarding known and unknown baseline risk factors (Downs et al., 2010).

Plyometric training was used in three studies (Asadi, 2013; Asadi et al., 2015; Cherni et al., 2019). Although variables commonly studied in response to periodized training programs are strength, speed, and muscle power, plyometric training has also been shown to improve postural control and balance. Plyometric exercises may increase neuromuscular coordination by training the nervous system, thus building automated movements during the activity. Therefore, increase in neural efficiency and neuromuscular performance justify the choice of this type of training (Davies et al., 2015; Petushek Luke R.; Ebben William P., 2010).

Neuromuscular and proprioceptive exercises were also observed in this review. These exercises have been frequently used to reduce the risk of lower limb injuries. Neuromuscular exercise mainly focuses on intrinsic risk factors such as previous injuries, reduced strength, flexibility, and balance. Proprioceptive exercise focuses on improving or restoring sensorimotor function (Aman et al., 2015; Emery et al., 2015; Mohammadi, 2007).

No adverse effects of neuromotor exercises were found. However, Benis, Bonato, and Torre (2016) observed a total of 93 injuries in lower limbs during the season (24 weeks), mainly in the control group. This may suggest a possible reduction in the risk of injury in athletes who received neuromotor training since poor balance has been associated with increased risk of ankle injury in some sports (e.g., soccer, basketball, and football).

To the best of our knowledge, there is no systematic review of the effects of neuromotor exercise on basketball players. The available studies include diversified sport modalities, and players are not from the same group age, which limit the generalization to basketball players.

This systematic review has some limitations that must be considered. Training protocols were heterogeneous among studies, some studies were missing data, or the available data was unclear. To minimize these limitations, we grouped similar treatment protocols and contacted authors of articles with missing data to obtain more information. However, we only received response from one author (Benis et al., 2016). Consequently, our meta-analysis was restricted to a few studies (Asadi, 2013; Asadi et al., 2015; Benis et al., 2016).

This strength of this review is the meta-analysis statistical technique, assessment of confounding factors, assessment of certainty of evidence (GRADE), isolation of a sport and age group, and low risk of bias in measuring results. All studies presented efficient outcome measurement to assess dynamic balance, except Domeika et al. (2020), which results might be influenced by the fact that evaluators were aware of the group participants were assigned (Asadi, 2013; Asadi et al., 2015; Benis et al., 2016; Bonato et al., 2018; Cherni et al., 2019; Domeika et al., 2020). The inclusion of studies that used the SEBT, a reliable and easy to reproduce test, is also a strength (Plisky et al., 2006). Force platform is also a reliable method. However, it needs experienced evaluators and has a high cost (Alonso et al., 2014).

Future studies on neuromotor exercises in basketball players should control selection bias respecting randomization and allocation into groups processes. Also, reporting bias should be controlled to reduce selective reporting of outcomes and results. In addition, it would be important to monitor players after the intervention period to evaluate the long-term effect of neuromotor exercises.

Neuromotor exercises seem to improve dynamic balance in basketball athletes, and they can be easily introduced into the athletes' training routine. It is important to highlight that balance should be assessed as an evolution parameter in basketball players. SEBT is an easy-to-reproduce test that can be easily introduced into clinical practice.

5. Conclusion

Our main finding was that neuromotor exercises for lower limbs improve dynamic balance in basketball players. Given the results found, we suggest to our readers/researchers the implementation of this type of exercise in the practice of basketball players. The improvement of the dynamic balance may result in better performance during changes in directions required by the sport and may reduce the risk of non-contact injuries to the lower limbs. However, the certainty of evidence is still very low. Therefore, our data should be cautiously interpreted.

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References

Alonso, A. C., Luna, N. M., Dionísio, F. N., Speciali, D. S., Leme, L. E. G., & Greve, J. M. D. (2014). Functional Balance Assessment: review. Medical Express, 1(6), 298–301. https://doi.org/10.5935/medicalexpress.2014.06.03

Aman, J. E., Elangovan, N., Yeh, I.-L. L., & Konczak, J. J. (2015). The effectiveness of proprioceptive training for improving motor function: a systematic review. Frontiers in Human Neuroscience, 8(JAN), 1075. https://doi.org/10.3389/fnhum.2014.01075

Asadi, A. (2013). Effects of in-season plyometric training on sprint and balance performance in basketball players. Sport Science, 6(1), 24–27.

Asadi, A., Saez De Villarreal, E., & Arazi, H. (2015). The Effects of Plyometric Type Neuromuscular Training on Postural Control Performance of Male Team Basketball Players. Journal of Strength and Conditioning Research, 29(7). https://doi.org/10.1519/JSC.0000000000000832

Balshem, H., Helfand, M., J Schünemann, H., D Oxman, A., Kunz, R., Brozek, J., E Vist, G., Falck-Ytter, Y., Meerpohl, J., Norris, S., & H Guyatt, G. (2011). GRADE guidelines: 3. Rating the quality of evidence. Journal of Clinical Epidemiology, 64(4), 401–406. https://doi.org/10.1016/J.JCLINEPI.2010.07.015

Benis, R., Bonato, M., & la Torre, A. la. (2016). Elite Female Basketball Players' Body-Weight Neuromuscular Training and Performance on the Y-Balance Test. Journal of Athletic Training, 51(9), 688–695. https://doi.org/10.4085/1062-6050-51.12.03

Bonato, M., Benis, R., & la Torre, A. (2018). Neuromuscular training reduces lower limb injuries in elite female basketball players. A cluster randomized controlled trial. Scandinavian Journal of Medicine and Science in Sports, 28(4), 1451–1460. https://doi.org/10.1111/sms.13034

Bouteraa, I., Negra, Y., Shephard, R. J., & Chelly, M. S. (2020). Effects of Combined Balance and Plyometric Training on Athletic Performance in Female Basketball Players. Journal of Strength and Conditioning Research, 34(7), 1967–1973. https://doi.org/10.1519/JSC.0000000000002546

Brachman, A., Kamieniarz, A., Michalska, J., Pawłowski, M., Słomka, K. J., & Juras, G. (2017). Balance Training Programs in Athletes-A Systematic Review. Journal of Human Kinetics, 58(1), 45–64. https://doi.org/10.1515/hukin-2017-0088

Caldemeyer, L. E., Brown, S. M., & Mulcahey, M. K. (2020). Neuromuscular training for the prevention of ankle sprains in female athletes: a systematic review. Physician and Sportsmedicine, 48(4), 363–369. https://doi.org/10.1080/00913847.2020.1732246

Cherni, Y., Jlid, M. C., Mehrez, H., Shephard, R. J., Paillard, T., Chelly, M. S., & Hermassi, S. (2019). Eight weeks of plyometric training improves ability to change direction and dynamic postural control in female basketball players. Frontiers in Physiology, 10(JUN). https://doi.org/10.3389/fphys.2019.00726

Chodzko-Zajko, W. J., Proctor, D. N., Fiatarone Singh, M. A., Minson, C. T., Nigg, C. R., Salem, G. J., & Skinner, J. S. (1998). American College of Sports Medicine Position Stand. Exercise and physical activity for older adults. In Medicine and science in sports and exercise (Vol. 30, Issue 6, pp. 992–1008). Med Sci Sports Exerc. https://doi.org/10.1249/MSS.0b013e3181a0c95c

Davies, G., Riemann, B. L., & Manske, R. (2015). Current concepts of plyometric exercise. International Journal of Sports Physical Therapy, 10(6), 760–786.

Domeika, A., Slapšinskaitė, A., Razon, S., Šiupšinskas, L., Klizienė, I., & Dubosienė, M. (2020). Effects of an 8-week basketball-specific proprioceptive training with a single-plane instability balance platform. Technology and Health Care, 1–11. https://doi.org/10.3233/thc-208002

Downs, M., Tucker, K., Christ-Schmidt, H., & Wittes, J. (2010). Some practical problems in implementing randomization. Clinical Trials, 7(3), 235–245. https://doi.org/10.1177/1740774510368300

Emery, C. A., Roy, T. O., Whittaker, J. L., Nettel-Aguirre, A., & van Mechelen, W. (2015). Neuromuscular training injury prevention strategies in youth sport: A systematic review and meta-analysis. British Journal of Sports Medicine, 49(13), 865–870. https://doi.org/10.1136/bjsports-2015-094639

Fitzgerald, G. K., Axe, M. J., & Snyder-Mackler, L. (2000). The efficacy of perturbation training in nonoperative anterior cruciate ligament rehabilitation programs for physical active individuals. 128–140. https://doi.org/10.1093/ptj/80.2.128

Garber, C. E., Blissmer, B., Deschenes, M. R., Franklin, B. A., Lamonte, M. J., Lee, I. M., Nieman, D. C., & Swain, D. P. (2011). American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: Guidance for prescribing exercise. Medicine and Science in Sports and Exercise, 43(7), 1334–1359. https://doi.org/10.1249/MSS.0b013e318213fefb

Goddard, E. C., & Dickey, J. P. (2019). Exercise Acutely Improves Dynamic Balance in Individuals with Unilateral Knee Osteoarthritis. International Journal of Human Movement and Sports Sciences, 7(1), 5–11.

Gribble, P. A., Hertel, J., & Plisky, P. (2012). Using the Star Excursion Balance Test to Assess Dynamic Postural-Control Deficits and Outcomes in Lower Extremity Injury: A Literature and Systematic Review. Journal of Athletic Training, 47(3), 339–357. https://doi.org/10.4085/1062-6050-47.3.08

Han, J., Anson, J., Waddington, G., Adams, R., & Liu, Y. (2015). The Role of Ankle Proprioception for Balance Control in relation to Sports Performance and Injury. BioMed Research International, 2015, 842804. https://doi.org/10.1155/2015/842804

Harmer, P. A. (2005). Basketball Injuries. In Epidemiology of Pediatric Sports Injuries (Vol. 49, pp. 31–61). KARGER. https://doi.org/10.1159/000085341

Higgins, J. P. T., Altman, D. G., Gøtzsche, P. C., Jüni, P., Moher, D., Oxman, A. D., Savović, J., Schulz, K. F., Weeks, L., & Sterne, J. A. C. (2011). The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. BMJ (Online), 343(7829). https://doi.org/10.1136/bmj.d5928

Higgins, J. P. T., Savović, J., Page, M. J., Elbers, R. G., & Sterne, J. A. C. (2019). Assessing risk of bias in a randomized trial. In Cochrane Handbook for Systematic Reviews of Interventions (pp. 205–228). wiley. https://doi.org/10.1002/9781119536604.ch8

Higgins, J. P., Thomas, J., Chandler, J., Cumpston, M., Li, T., Page, M. J., & Welch, V. A. (2019). Cochrane Handbook for Systematic Reviews of Interventions (2nd ed.). John Wiley & Sons.

Hrysomallis, C. (2007). Relationship between balance ability, training and sports injury risk. Sports Medicine, 37(6), 547–556.

Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C., Gøtzsche, P. C., Ioannidis, J. P. A., Clarke, M., Devereaux, P. J., Kleijnen, J., & Moher, D. (2009). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: Explanation and elaboration. In PLoS Medicine (Vol. 6, Issue 7). https://doi.org/10.1371/journal.pmed.1000100

McGuine, T. A., Greene, J. J., Best, T., & Leverson, G. (2000). Balance as a predictor of ankle injuries in high school basketball players. Clinical Journal of Sport Medicine, 10(4), 239–244. https://doi.org/10.1097/00042752-200010000-00003

McGuine, TA., & Keene, JS. (2017). The Effect of a Balance Training Program on the Risk of Ankle Sprains in High School Athletes: Am J Sports Med, 34(7), 1103–1111.

Mohammadi, F. (2007). Comparison of 3 preventive methods to reduce the recurrence of ankle inversion sprains in male soccer players. American Journal of Sports Medicine, 35(6), 922–926. https://doi.org/10.1177/0363546507299259

Notarnicola, A., Maccagnano, G., Tafuri, S., Pesce, V., Digiglio, D., & Moretti, B. (2015). Effects of training on postural stability in young basketball players. Muscles, Ligaments and Tendons Journal, 5(4), 310–315. https://doi.org/10.11138/mltj/2015.5.4.310

Petushek Luke R.; Ebben William P., E. J. ; G. (2010). Force, velocity, and power adaptations in response to a periodized plyometric training program. 28 International Conference on Biomechanics in Sports.

Plisky, P. J., Gorman, P. P., Butler, R. J., Kiesel, K. B., Underwood, F. B., & Elkins, B. (2009). The reliability of an instrumented device for measuring components of the star excursion balance test. North American Journal of Sports Physical Therapy : NAJSPT, 4(2), 92–99.

Plisky, P. J., Rauh, M. J., Kaminski, T. W., & Underwood, F. B. (2006). Star Excursion Balance Test as a Predictor of Lower Extremity Injury in High School Basketball Players. Journal of Orthopaedic & Sports Physical Therapy, 36(12), 911–919. https://doi.org/10.2519/jospt.2006.2244

Sekulic, D., Spasic, M., Mirkov, D., Cavar, M., & Sattler, T. (2013). Gender-specific influences of balance, speed, and power on agility performance. Journal of Strength and Conditioning Research, 27(3), 802–811. https://doi.org/10.1519/JSC.0b013e31825c2cb0

Stiffler, M. R., Bell, D. R., Sanfilippo, J. L., Hetzel, S. J., Pickett, K. A., & Heiderscheit, B. C. (2017). Star Excursion Balance Test Anterior Asymmetry Is Associated With Injury Status in Division I Collegiate Athletes. Journal of Orthopaedic & Sports Physical Therapy, 47(5), 339–346.

Taylor, J. B., Ford, K. R., Nguyen, A.-D., Terry, L. N., & Hegedus, E. J. (2015). Prevention of Lower Extremity Injuries in Basketball. Sports Health: A Multidisciplinary Approach, 7(5), 392–398. https://doi.org/10.1177/1941738115593441

van Lieshout, R., Reijneveld, E. A. E., van den Berg, S. M., Haerkens, G. M., Koenders, N. H., de Leeuw, A. J., van Oorsouw, R. G., Paap, D., Scheffer, E., Weterings, S., & Stukstette, M. J. (2016). Reproducibility of the modified star excursion balance test composite and specific reach direction scores. International Journal of Sports Physical Therapy, 11(3), 356–365.

Williams, D. S. B. B., Murray, N. G., & Powell, D. W. (2016). Athletes who train on unstable compared to stable surfaces exhibit unique postural control strategies in response to balance perturbations. 5(1), 70–76. https://doi.org/10.1016/j.jshs.2016.01.010