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Human Kinetics
BRIEF REVIEW

# The Effects of Lower-Extremity Plyometric Training on Soccer-Specific Outcomes in Adult Male Soccer Players: A Systematic Review and Meta-Analysis

**Peter A. van de Hoef, Jur J. Brauers, Maarten van Smeden, Frank J.G. Backx, and Michel S. Brink**

***Background:*** Plyometric training is a specific form of strength training that is used to improve the physical performance of athletes. An overview of the effects of plyometric training on soccer-specific outcomes in adult male soccer players is not available yet. ***Purpose:*** To systematically review and meta-analyze the effects of plyometric training on soccer-specific outcome measures in adult male soccer players and to identify which programs are most effective. ***Methods:*** PubMed, Embase/Medline, Cochrane, PEDro, and Scopus were searched. Extensive quality and risk of bias assessments were performed using the Cochrane ROBINS 2.0 for randomized trials. A random effects meta-analysis was performed using Cochrane Review Manager 5.3. ***Results:*** Seventeen randomized trials were included in the meta-analysis. The impact of plyometric training on strength, jump height, sprint speed, agility, and endurance was assessed. Only jump height, 20-m sprint speed, and endurance were significantly improved by plyometric training in soccer players. Results of the risk of bias assessment of the included studies resulted in overall scores of some concerns for risk of bias and high risk of bias. ***Conclusion:*** This review and meta-analysis showed that plyometric training improved jump height, 20-m sprint speed, and endurance, but not strength, sprint speed over other distances, or agility in male adult soccer players. However, the low quality of the included studies and substantial heterogeneity means that results need to be interpreted with caution. Future high-quality research should indicate whether or not plyometric training can be used to improve soccer-specific outcomes and thereby enhance performance.

***Keywords:*** plyometric exercise, football, football-specific outcomes, performance, sprint speed

Soccer consists of repeated high-intensity activities,[1] such as sprinting, jumping, and changing direction,[2,3] and requires players to have excellent strength and endurance to cope with the physical demands of the game.[1–3] A specific form of strength training that is used widely in team sports to meet these demands and improve physical performance is plyometric training.

Plyometric exercises are characterized by explosive muscle extension and contraction and are thought to improve neural efficiency.[4] These specific exercises consist of 3 phases: (1) the (eccentric) preactivation phase, (2) the (isometric) amortization phase, and (3) the (concentric) shortening phase.[4] In the eccentric preactivation phase, the Golgi tendon organs are stretched more than in regular strength training. This leads to a greater inhibition of the protective function of the Golgi tendon and a greater concentric power output.[4,5] In other words, plyometric training can strengthen the elastic properties of connective tissue, improve the mechanical characteristics of the muscle–tendon complex, and optimize cross-bridge mechanics and motor unit activation.[6,7] These adaptations are associated with increased joint stiffness, improved muscle strength, increased contraction speed, and improved dynamic stability and neuromuscular control.[5–7] Consequently, these exercises might increase jump height, sprint speed, agility, and endurance.[8]

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Several studies have focused on effects of plyometric training programs on sport-specific outcomes. Most of these studies assessed sprint speed, jump height, agility, and endurance in a variety of sports and age categories.[4,6,9,10] Soccer differs significantly from other intermittent team sports because of the rules of the game and field size. This results in unique game demands illustrated by the high number of sprints over both short and long distances, time in high-velocity running, duration of low-intensity activity, number of jumps, and long duration of matches.[11,12] Because of the different intensity and demands of soccer relative to other team sports, physical capacities of soccer players might be different compared with other team-sport athletes. As physical capacities are key factors in effects of training interventions, and plyometric training is mostly added to regular sport-specific training, it is unclear how the results of earlier studies can be generalized to adult male soccer players. Moreover, a better insight into the characteristics of these interventions (training dose) is needed to determine which programs are most effective. Therefore, the aim of this study was to systematically review and meta-analyze the effects of plyometric training on soccer-specific outcomes in adult male soccer players and to determine which programs seem to be most effective.

## Methods

### Study Design and Registration

PubMed, Embase/Medline, Scopus, PEDro, and Cochrane databases were systematically searched for articles describing the soccer-specific effects of plyometric training in adult players. Sport-specific outcomes included sprinting, jumping, agility, strength, repeated-sprint ability, and endurance. This systematic review follows the preferred reporting items for systematic reviews and meta-analysis (PRISMA) guidelines and was registered in the international prospective register for systematic reviews (PROSPERO) with reference number CRD42019082664 on February 1, 2019.[13,14]

## Search Strategy and Study Selection

Keywords related to the population (ie, male soccer players); type of training (ie, plyometric exercises, bounding exercises); and sport-specific outcomes (ie, strength, jumping, and sprint speed) were used. (The search string is provided in Appendix A.) The databases were searched for articles published up to February 1, 2019. Two researchers (P.A.H. and J.J.B.) independently screened titles and abstracts to identify articles meeting the inclusion criteria described below. The full text of the selected articles was retrieved and independently screened by the same researchers to determine whether articles met the inclusion criteria. The reference lists of the included articles were checked to ensure no publications were missed by the initial search.

## Inclusion and Exclusion Criteria

Plyometric training in soccer players is mostly incorporated in regular soccer training. To assess the additional benefit of plyometric training on regular soccer training, studies were included if they met the following 3 criteria: (1) focused on adult male soccer players; (2) compared a plyometric training intervention with a control group or another intervention; and (3) described soccer-specific outcome measures (ie, strength, jumping, sprinting, agility, or endurance). All nonrandomized studies, qualitative studies, reviews, and cross-sectional studies were excluded, as were articles not written in English, articles that were not available in full text, articles with only sprint training as intervention, and articles studying acute postexercise effects. Articles were excluded when insufficient data were reported to allow meta-analysis, and additional data could not be retrieved by contacting the corresponding authors. Data were considered insufficient if postintervention means and SDs were not reported or the results were reported only in graphical form. When studies compared 3 or more groups, we only compared the plyometric training group with the "regular training group."

## Quality Assessment and Risk of Bias Assessment

Two authors (P.A.H. and J.J.B.) independently performed quality and risk of bias assessments for the included studies. Cochrane Robins 2.0 for randomized trials was used.[15] This tool assesses methodological quality and indicates a potential risk of bias on the basis of 6 aspects: (1) randomization process, (2) effects of assignment to intervention, (3) effects of adherence to intervention, (4) missing outcome data, (5) risk of bias in measurement of the outcome, and (6) risk of bias in the reported results. The overall judgement was summarized as "low risk of bias," "some concerns," or "high risk of bias." The publication bias assessment is visualized in a funnel plot per outcome measure. If the 2 assessors did not agree about article selection, quality assessment, or risk of bias assessment, consensus was sought in a meeting. If necessary, the fifth author (M.S.B.) was consulted to make the final decision.

## Data Extraction and Data Synthesis

A standardized data extraction form was developed consisting of the name of the first author; year of the publication; study design; number and description of the participants; type of intervention; training frequency, intensity, and duration of the intervention; control intervention; the type of measurements; and reported effect sizes. Meta-analysis was performed on the extracted data using Cochrane Review Manager (RevMan) [computer program] (version 5.3; The Nordic Cochrane Centre, The Cochrane Collaboration, 2014, Copenhagen, Denmark).[16] Heterogeneity was checked using a random effects meta-analysis model; effect sizes and the $I^2$ statistic were calculated.

When different instruments were used to measure the same outcome, performance tests were matched based on distances, number of repetitions, and directional changes. When the outcomes of sprint tests were reported as an average speed, this was converted to time to complete the test. For agility, data from the agility *t* test and the zigzag change of direction (zigzag COD) were combined in the analysis. Strength was measured with double-legged 1 repetition maximum (1RM) test and single-legged 1RM test. The double-legged 1RM test results were pooled in the analysis. The single-legged peak power measurement was excluded because these data cannot be converted to a double-legged 1RM.[17] Due to differences in intervention designs and study protocols, large heterogeneity in the extracted data ($I^2 > 60\%$) was expected.

# Results

## Literature Search

The electronic database search identified 778 articles. A total of 524 duplicates were removed, and the remaining 523 titles and abstracts were screened. The full text of 42 articles was retrieved and assessed for eligibility. Of these 42 articles, 17 articles were included in the analysis (Figure 1).

Cohen kappa for title and abstract selection and for full-text selection was 0.75 and 0.67, respectively, indicating substantial agreement between the 2 researchers (P.A.H. and J.J.B.) in article selection.[18]

## Study Description

The studies included in this review used a variety of plyometric training programs and included soccer players competing at an amateur (N = 3), semiprofessional (N = 5), and professional (N = 9) levels (Table 1). The plyometric training programs varied in frequency, intensity, duration, time in season when given, and mode and sequence of the exercises. Ten of the included studies compared the intervention with regular training. Four of these 10 studies investigated solely a plyometric training program,[23,28,30,32] 4 studies added strength training to the plyometric program,[17,21,22,29] 1 study added sprint training to a complex program,[20] and 1 study investigated a high-intensity intermittent training program.[33]

Six studies compared 2 plyometric training programs. Arcos et al[19] compared a combination of horizontal plus vertical exercises with solely vertical exercises, where the horizontal plus vertical group was considered as the intervention group. Loturco et al[24–27] compared plyometric programs of different intensities and velocities or power-based loads. The increased velocity groups,[24,25] optimal load group,[26] and the optimum power load plus plyometrics group[27] were considered as the intervention groups. One study[34] compared 2 plyometric programs with different number of repetitions, where the group with the most repetitions was considered as the intervention group.[34] The last study compared a plyometric training program with strength training.[31]

The frequency, intensity, duration, timing, and the design of the intervention differed between the studies. The frequency of plyometric training during the week varied from 2 to 4 times a week. Training intensity was described in terms of number of

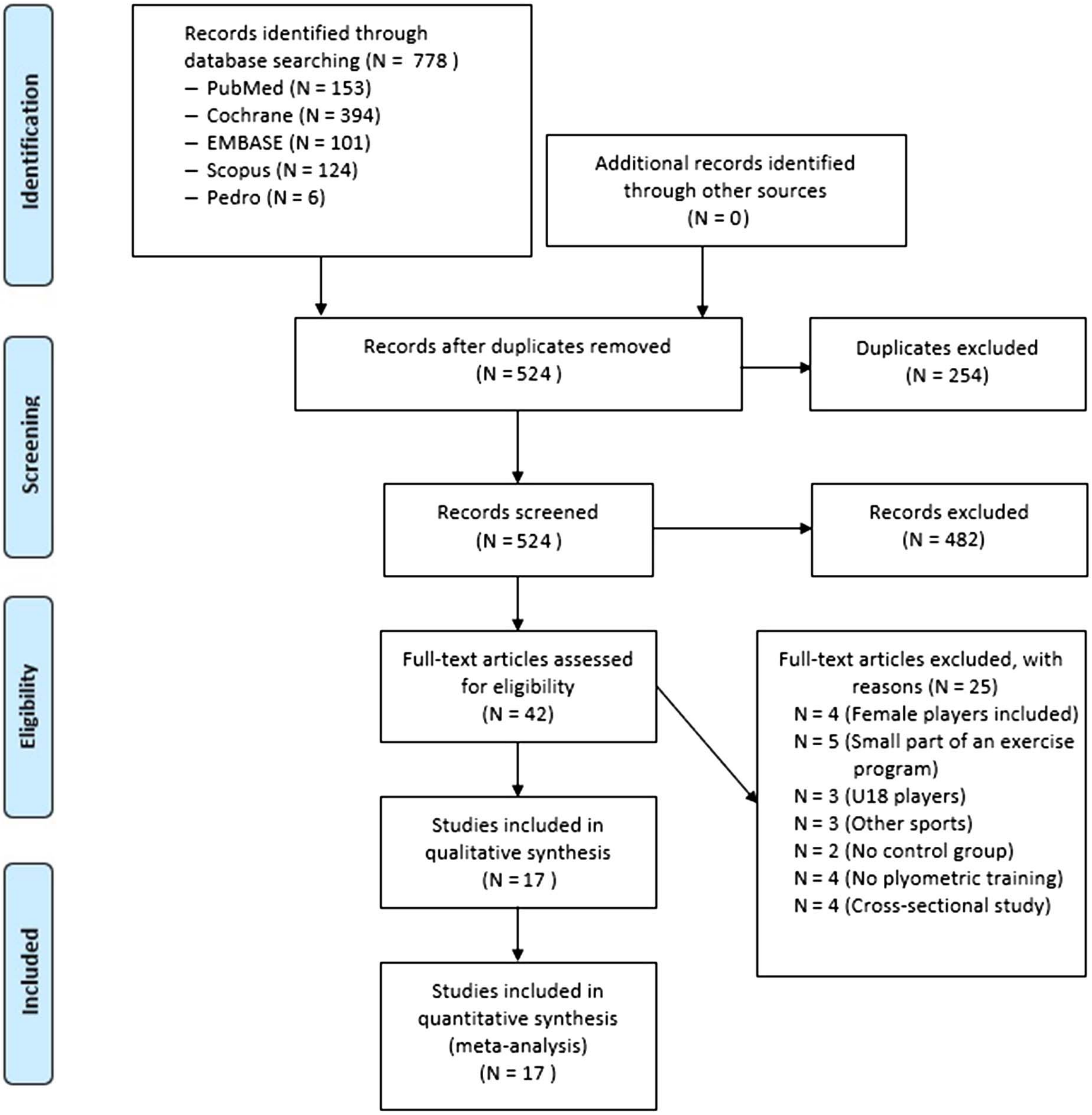


**Figure 1** — PRISMA flowchart.[13]

| Study or subgroup | Experimental Mean (kg) | Experimental SD (kg) | Experimental Total | Control Mean (kg) | Control SD (kg) | Control Total | Weight | Mean difference IV, random, 95% CI (kg) |
|---|---|---|---|---|---|---|---|---|
| Faude et al (2013) | 170 | 20.2 | 8 | 151.4 | 24.5 | 8 | 13.0% | 18.60 (−3.40 to 40.60) |
| Loturco et al (2013) | 107.63 | 8.29 | 16 | 111.44 | 13.07 | 16 | 15.3% | −3.81 (−11.39 to 3.77) |
| Loturco et al (2015) | 187.25 | 19.74 | 12 | 185.5 | 28.58 | 12 | 13.4% | 1.75 ( −17.90 to 21.40) |
| Loturco et al (2016) | 115.57 | 8.8 | 11 | 115.3 | 6.7 | 12 | 15.4% | 0.27 (−6.17 to 6.71) |
| Rodríguez-Rosell et al (2017) | 104.4 | 17.8 | 10 | 91.6 | 17.9 | 10 | 14.2% | 12.80 (−2.85 to 28.45) |
| Ronnestad et al (2008) | 220 | 3 | 8 | 183 | 2 | 7 | 15.6% | 37.00 (34.45 to 39.55) |
| Spineti et al (2015) | 146.2 | 21.776 | 10 | 155.5 | 29.4 | 12 | 13.1% | −9.30 (−30.72 to 12.12) |
| **Total (95% CI)** | | | **75** | | | **77** | **100.0%** | 8.49 (−10.64 to 27.61) |

Heterogeneity: $\tau^2 = 607.97$; $\chi^2 = 209.39$, df = 6 ($P < .001$); $I^2 = 97\%$
Test for overall effect: $Z = 0.87$ ($P = .38$)

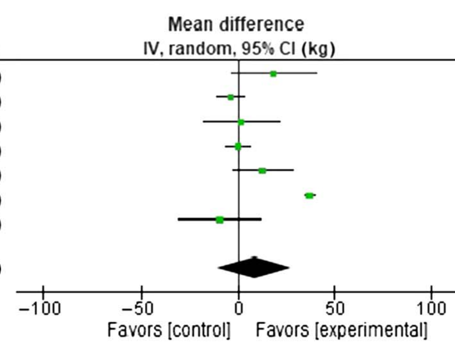


**Figure 2** — Forest plot of strength as outcome measure of plyometric training.

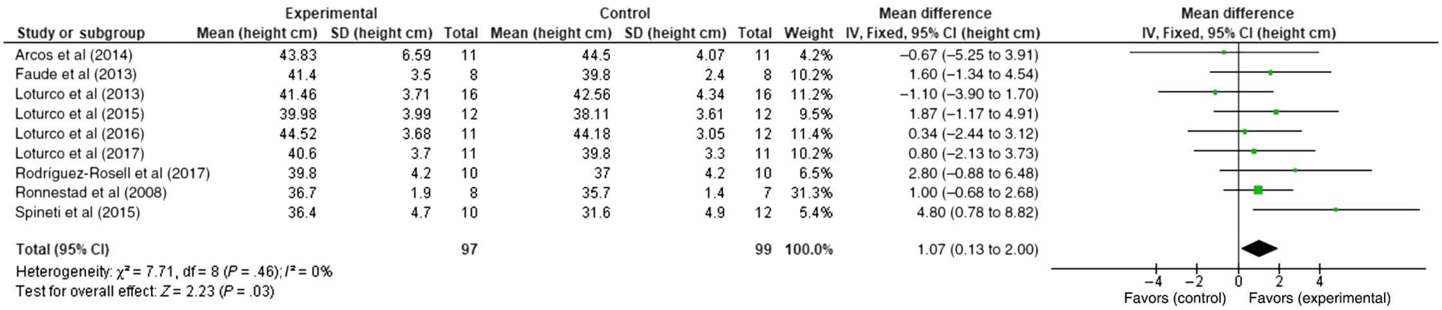


**Figure 3** — Forest plot of jump height as outcome measure of plyometric training.

## Table 1 Study Demographics

| Authors | Population | Country | Type of training | Duration and intensity | Comparison | Timing of intervention |
|---|---|---|---|---|---|---|
| Arcos et al[19] | Professional soccer players, male (n = 15), age 20.3 (1.9) y/19.6 (1.6) y | Spain | Horizontal and vertical PT + ST | 8 wk, 1–2 training sessions/wk of 25–30 min, intensity per exercise is set at percentage of peak power or body weight | Vertical PT + ST | Preseason |
| Boer and Van Aswegen[20] | Elite soccer players, male, (n = 46), age 21.7 (1.8) y | South Africa | Complex training | 6 wk, 3×/wk, 25 min/session, 6 reps 80%–90% of 1RM (resistance training)/5-m skipping, 8 jumps. Six maximum jumps (PT) | No supervised training | Preseason |
| Brito et al[21] | Amateur (college) soccer players, male (n = 57), age 19.9–20.7 (0.5–1.0) y | Portugal | ST + PT | 9 wk, 2×/wk, 15–20 min/session | Regular training | In season |
| Faude et al[22] | Professional soccer players, male (n = 22), age 23.1 (2.7) y, 22.6 (2.4) y | Switzerland | ST + PT | 7 wk, 2×/wk, 30 min | Regular training | In season |
| Jovanovic et al[23] | Professional soccer players, male (n = 100), age 19 y, 19 y | Croatia | PT | 8 wk, 3×/wk, duration N/A | Regular training | In season |
| Loturco et al[24] | Professional soccer players, male (n = 32), age 19.1 (0.7) y, 19.1 (0.7) y | Brazil | PT + ST | 6 wk, 2×/wk training program, and 4×/week tactical and soccer-specific training | PT with increased velocity and decreased intensity | Preseason |
| Loturco et al[25] | Amateur soccer players, male (n = 24), age 18.7 (0.5) y, 18.4 (0.6) y | Brazil | PT | 6 wk, 2×/wk, duration N/A | Jump squat training reducing bar velocity by increasing weight | Preseason |
| Loturco et al[26] | Professional soccer players, male (n = 23), age 23.1 (3.2) y, 23.9 (4.4) y | Brazil | ST + PT | 6 wk, 3×/wk | Optimum power load (OPL) jump squats | Between state first division and Series C National Championships |
| Loturco et al[27] | Professional soccer players, male (n = 22), age 21.7 (2.4) y, 22.2 (2.4) y | Brazil | PT | 5 wk, 2×/wk training program, and 6×/wk tactical and technical training | OPL + resisted sprint training | Preseason |
| Mendiguchia et al[17] | Amateur male soccer players, male (n = 60), age 22.7 (4.8) y, 21.8 (2.5) y | Spain | ST + PT | 7 wk, 2×/wk, 30–35 min | Regular soccer training | First half of the season |

*(continued)*

**Table 1 (continued)**

| Authors | Population | Country | Type of training | Duration and intensity | Comparison | Timing of intervention |
|---|---|---|---|---|---|---|
| Nakamura et al[28] | Semiprofessional and regional league college soccer players, male (n = 29), age 22.9 (2.3) y | Japan | PT | 3 wk, 2×/wk, 45 min/session, 1 episode of 3 sets square jumps 2 × 10 jumps (60 jumps total), 1 episode of 3 sets forward bounding 1 × 16.5 m 64 jumps | Regular training | Off-season (post) |
| Rodríguez-Rosell et al[29] | Semiprofessional soccer players, male (n = 30), age 24.5 (3.4) y | Spain | ST + PT | 6 wk, 2×/wk, 35 min/session, ST progressively increasing from ~45% to 58% of 1RM/PT: not reported | Regular training | In season |
| Ronnestad et al[30] | Professional soccer players, male (n = 21), plyo group: age 23.0 (2) y, ST group: age 22.0 (2.5) y, Control group: age 24.0 (1.5) y | Norway | ST + PT | 7 wk, 2× /wk, plyo group: 2–4 sets, 5–10 foot contacts/ST: 4–6 RM with increasing loads, building up from 3 sets to 5 sets | Core training | Preseason |
| Spineti et al[31] | Semiprofessional (under 20) soccer players (first Brazilian league), male, (n = 22), age 18.4 (0.4) y | Brazil | Complex/contrast training | 8 wk, 3×/wk, 3 sequences of 2 sets, CMJ1: 6 reps@60% PP, frontal jumps: 10×, 40 cm height/80 cm long, high pull power: 5RM, sprint: 10 m, knee up + sprint: 5 + 10 m, zigzag: 4 × 5 m, CMJ2: 4 reps@100%pp, single jump on box: 10×, 50 cm height, depth "box": 10× 50 cm height, depth: 10 jumps, 50 cm height | ST | In season |
| Váczi et al[32] | Semiprofessional (third league) soccer players, male, (n = 24), plyo group: age 21.9 (1.7) y/CG: 22.7 (1.4) y | Hungary | PT | 6 wk, 2×/wk, 2 wk preparatory, 3 wk increased volume, 1 wk decreased volume to taper. DLHJ: 4 × 5/6 × 5/3 × 5, SLLCJ: 3 × 10/4 × 10/2 × 10, SLFH: 3 × 5/4 × 5/2 × 5, DLDJ: 4 × 5/6 × 5/2 × 5, DLLCJ: 4 × 5/6 × 5/2 × 5, SLHJ: 3 × 10/4 × 10/2 × 10. Total unilateral foot contacts/leg/session: 20–60, total bilateral foot contacts/session: 20–60 | Regular training | N/A |
| Wells et al[33] | Professional soccer players, male (n = 16), age 21.3 (2.1) y | N/A | High-intensity training | 6 wk, 3×/wk, 4–14 sets of 60–10 s >18 kmh | Regular training | In season |
| Yanci et al[34] | Semiprofessional soccer players, male (n = 21), age 22.50 (5.04) y, 24.63 (2.72) y | Spain | PT | 6 wk, 2×/wk, 360 foot contacts vs 180 foot contacts | PT with half the volume | In season |

Abbreviations: CG, control group; CMJ, countermovement jump; DLDJ, double-leg depth jump; DLHJ, double-leg hurdle jump; DLLCJ, double-leg lateral cone jump; PT, plyometric training; SLFH, single-leg forward hop; SLHJ, single-leg hurdle jump; SLLCJ, single-leg lateral cone jump; ST, strength training.

repetitions, number of acute bouts, number of foot contacts, percentages of maximum strength, frequency of training during the week, and duration of the training. The programs lasted 5 to 9 weeks. The timing of the intervention varied from the preseason (7 studies), in season (8 studies), and off-season (1 study); 1 study did not describe the timing clearly. The mode and sequence of the exercises (design of the program) varied remarkably.

The outcomes included in this systematic review and meta-analysis were as follows: strength, jump height, sprint speed, agility, and endurance. No studies evaluating repeated-sprint ability were found.

## Strength

Ten studies measured strength as outcome for plyometric training,[17,21,22,24–26,29,30,31,32] assessed with the leg press,[25] dynamometer,[21,22,32] Biodex testing,[17] half squats,[22,30] squats,[21,24,26,29,31] and a custom-built isokinetic dynamometer.[32] We chose to plot the values of overall strength expressed in kilograms (Figure 2). Overall strength was not reported in 1 study,[17] and 1 study did express overall strength in newtons per meter instead of kilograms.[32] Differences in study design and measurements resulted in data heterogeneity. In addition, the risk of bias assessment in combination with the funnel plots indicated a high risk of bias.

## Jump Height

Eleven studies used the countermovement jump (CMJ) to measure the effects of plyometric training on jump height.[19,21–27,29,30,31] Nine studies were included in this meta-analysis and showed an overall significant effect of an increase of 1.07 cm on the CMJ in favor of the plyometric training programs (1.07, 95% CI, 0.13–2.00) (Figure 3).[19,22,24–27,29,30,31] Two studies did not report data means and SDs, but predifference and postdifference in percentages only.[21,23] One of these 2 studies reported the plyometric exercises to have no effect on the CMJ[21] and the other that the exercises significantly improved the CMJ.[23]

## Sprint Speed

Thirteen studies reported sprint time over 5 to 50 m as outcome. The most used distance was 10 m,[22,23,24–26,29,28,30] followed by 20 m,[21,23,25–27,28,29] 5 m,[19,21,23,25,26,28,34] 30 m,[20,22,23,24,27] and 40 m[30] (Figures 4–8). The data from some studies were incomplete and could therefore not be included in the meta-analysis.[21,23]

Plyometric exercise increased sprint speed over 20 m (Figure 7), but not over the other distances (Figures 4–6, 8). Sprint speed over 40 m was increased in the plyometric training group and the plyometric + strength training compared with the control group, but there was no difference between the plyometric training and the plyometric + strength training groups.[30]

Funnel plots for the 10-m sprint test (Figure 9B) showed a skewed plot, which indicate a potential risk of publication bias.

## Agility

Agility was measured with the agility *t* test and the zigzag change of direction (COD) test. Five studies reported the best time for the tests postintervention,[25–27,32,34] 1 study reported the average time of the 2 best trials,[20] and those results were analyzed in the meta-analysis (Figure 10). The overall effect of these studies showed no improvement by plyometric training on agility. However, funnel plot analysis indicated a potential risk of publication bias (Figure 9G).

| | Experimental | | | Control | | | | Mean difference |
|---|---|---|---|---|---|---|---|---|
| Study or subgroup | Mean (s) | SD (s) | Total | Mean (s) | SD (s) | Total | Weight | IV, random, 95% CI (s) |
| Arcos et al (2014) | 0.96 | 0.03 | 11 | 0.96 | 0.04 | 11 | 39.3% | 0.00 (−0.03 to 0.03) |
| Brito et al (2014) | 0 | 0 | 0 | 0 | 0 | 0 | | Not estimable |
| Jovanovic et al (2011) | 0 | 0 | 0 | 0 | 0 | 0 | | Not estimable |
| Loturco et al (2015) | 1.05 | 0.04 | 12 | 1.05 | 0.05 | 12 | 26.1% | 0.00 (−0.04 to 0.04) |
| Loturco et al (2016) | 1.01 | 0.08 | 11 | 1.02 | 0.06 | 12 | 10.1% | −0.01 (−0.07 to 0.05) |
| Nakamura et al (2012) | 1.04 | 0.06 | 11 | 1.06 | 0.05 | 5 | 10.8% | −0.02 (−0.08 to 0.04) |
| Yanci et al (2016) | 1.02 | 0.06 | 8 | 1.02 | 0.04 | 8 | 13.7% | 0.00 (−0.05 to 0.05) |
| Total (95% CI) | | | 53 | | | 48 | 100.0% | −0.00 (−0.02 to 0.02) |

Heterogeneity: $\tau^2 = .00$; $\chi^2 = 0.48$, df = 4 ($P = .98$); $I^2 = 0\%$
Test for overall effect: $Z = 0.34$ ($P = .74$)

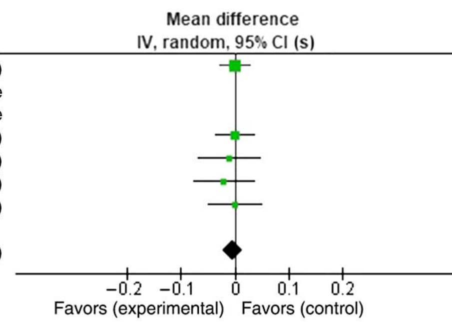


**Figure 4** — Forest plot of 5-m sprint time as outcome measure of plyometric training.

| | Experimental | | | Control | | | | Mean difference |
|---|---|---|---|---|---|---|---|---|
| Study or subgroup | Mean (s) | SD (s) | Total | Mean (s) | SD (s) | Total | Weight | IV, random, 95% CI (s) |
| Faude et al (2013) | 1.77 | 0.05 | 8 | 1.77 | 0.05 | 8 | 14.4% | 0.00 (−0.05 to 0.05) |
| Loturco et al (2013) | 1.74 | 0.1 | 16 | 1.74 | 0.1 | 16 | 8.3% | 0.00 (−0.07 to 0.07) |
| Loturco et al (2015) | 1.78 | 0.07 | 12 | 1.79 | 0.06 | 12 | 13.1% | −0.01 (−0.06 to 0.04) |
| Loturco et al (2016) | 1.66 | 0.07 | 11 | 1.72 | 0.07 | 12 | 11.3% | −0.06 (−0.12 to −0.00) |
| Nakamura et al (2012) | 1.81 | 0.08 | 11 | 1.79 | 0.08 | 5 | 5.8% | 0.02 (−0.06 to 0.10) |
| Rodríguez-Rosell et al (2017) | 1.71 | 0.08 | 10 | 1.78 | 0.06 | 10 | 10.0% | −0.07 (−0.13 to −0.01) |
| Ronnestad et al (2008) | 1.74 | 0.02 | 8 | 1.74 | 0.02 | 7 | 37.1% | 0.00 (−0.02 to 0.02) |
| Total (95% CI) | | | 76 | | | 70 | 100.0% | −0.01 (−0.04 to 0.01) |

Heterogeneity: $\tau^2 = .00$; $\chi^2 = 8.17$, df = 6 ($P = .23$); $I^2 = 27\%$
Test for overall effect: $Z = 1.26$ ($P = .21$)

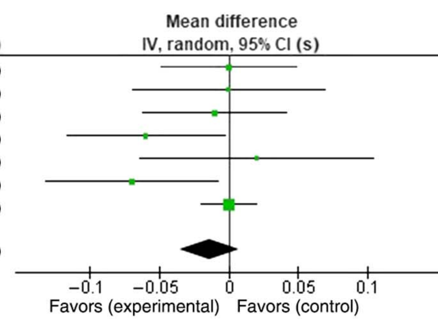


**Figure 5** — Forest plot of 10-m sprint time as outcome measure of plyometric training.

| | Experimental | | | Control | | | | Mean difference |
|---|---|---|---|---|---|---|---|---|
| Study or subgroup | Mean (s) | SD (s) | Total | Mean (s) | SD (s) | Total | Weight | IV, random, 95% CI (s) |
| Arcos et al (2014) | 2.29 | 0.08 | 11 | 2.3 | 0.09 | 11 | 56.3% | −0.01 (−0.08 to 0.06) |
| Yanci et al (2016) | 2.3 | 0.07 | 8 | 2.39 | 0.11 | 8 | 43.7% | −0.09 (−0.18 to 0.00) |
| Total (95% CI) | | | 19 | | | 19 | 100.0% | −0.04 (−0.12 to 0.03) |

Heterogeneity: $\tau^2 = .00$; $\chi^2 = 1.86$, df = 1 ($P = .17$); $I^2 = 46\%$
Test for overall effect: $Z = 1.13$ ($P = .26$)

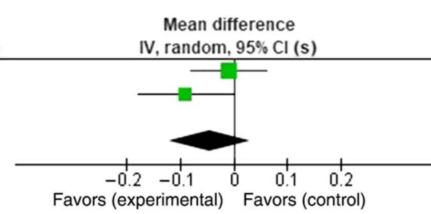


**Figure 6** — Forest plot of 15-m sprint time as outcome measure of plyometric training.

| Study or subgroup | Experimental Mean (s) | Experimental SD (s) | Experimental Total | Control Mean (s) | Control SD (s) | Control Total | Weight | Mean difference IV, random, 95% CI (s) |
|---|---|---|---|---|---|---|---|---|
| Loturco et al (2015) | 3.01 | 0.08 | 12 | 3.05 | 0.08 | 12 | 52.6% | −0.04 (−0.10 to 0.02) |
| Loturco et al (2016) | 2.9 | 0.13 | 11 | 3 | 0.16 | 12 | 15.3% | −0.10 (−0.22 to 0.02) |
| Nakamura et al (2012) | 3.13 | 0.13 | 11 | 3.1 | 0.15 | 5 | 9.3% | 0.03 (−0.12 to 0.18) |
| Rodríguez-Rosell et al (2017) | 2.97 | 0.14 | 10 | 3.06 | 0.07 | 10 | 22.9% | −0.09 (−0.19 to 0.01) |
| Total (95% CI) | | | 44 | | | 39 | 100.0% | −0.05 (−0.10 to −0.01) |

Heterogeneity: $\tau^2 = .00$; $\chi^2 = 2.46$, df = 3 ($P = .48$); $I^2 = 0\%$
Test for overall effect: $Z = 2.29$ ($P = .02$)

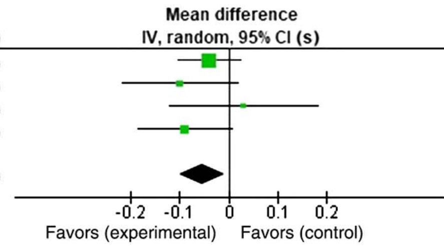


**Figure 7** — Forest plot of 20-m sprint time as outcome measure of plyometric training.

| Study or subgroup | Experimental Mean (s) | Experimental SD (s) | Experimental Total | Control Mean (s) | Control SD (s) | Control Total | Weight | Mean difference IV, random, 95% CI (s) |
|---|---|---|---|---|---|---|---|---|
| Boer et al (2016) | 4.2 | 0.2 | 17 | 4.2 | 0.3 | 13 | 11.3% | 0.00 (−0.19 to 0.19) |
| Faude et al (2013) | 4.27 | 0.09 | 8 | 4.19 | 0.09 | 8 | 51.7% | 0.08 (−0.01 to 0.17) |
| Loturco et al (2013) | 4.18 | 0.14 | 16 | 4.17 | 0.16 | 16 | 37.0% | 0.01 (−0.09 to 0.11) |
| Total (95% CI) | | | 41 | | | 37 | 100.0% | 0.05 (−0.02 to 0.11) |

Heterogeneity: $\tau^2 = .00$; $\chi^2 = 1.26$, df = 2 ($P = .53$); $I^2 = 0\%$
Test for overall effect: $Z = 1.39$ ($P = .16$)

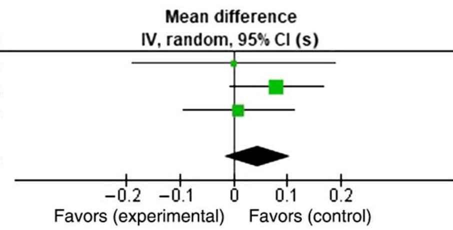


**Figure 8** — Forest plot of 30-m sprint time as outcome measure of plyometric training.

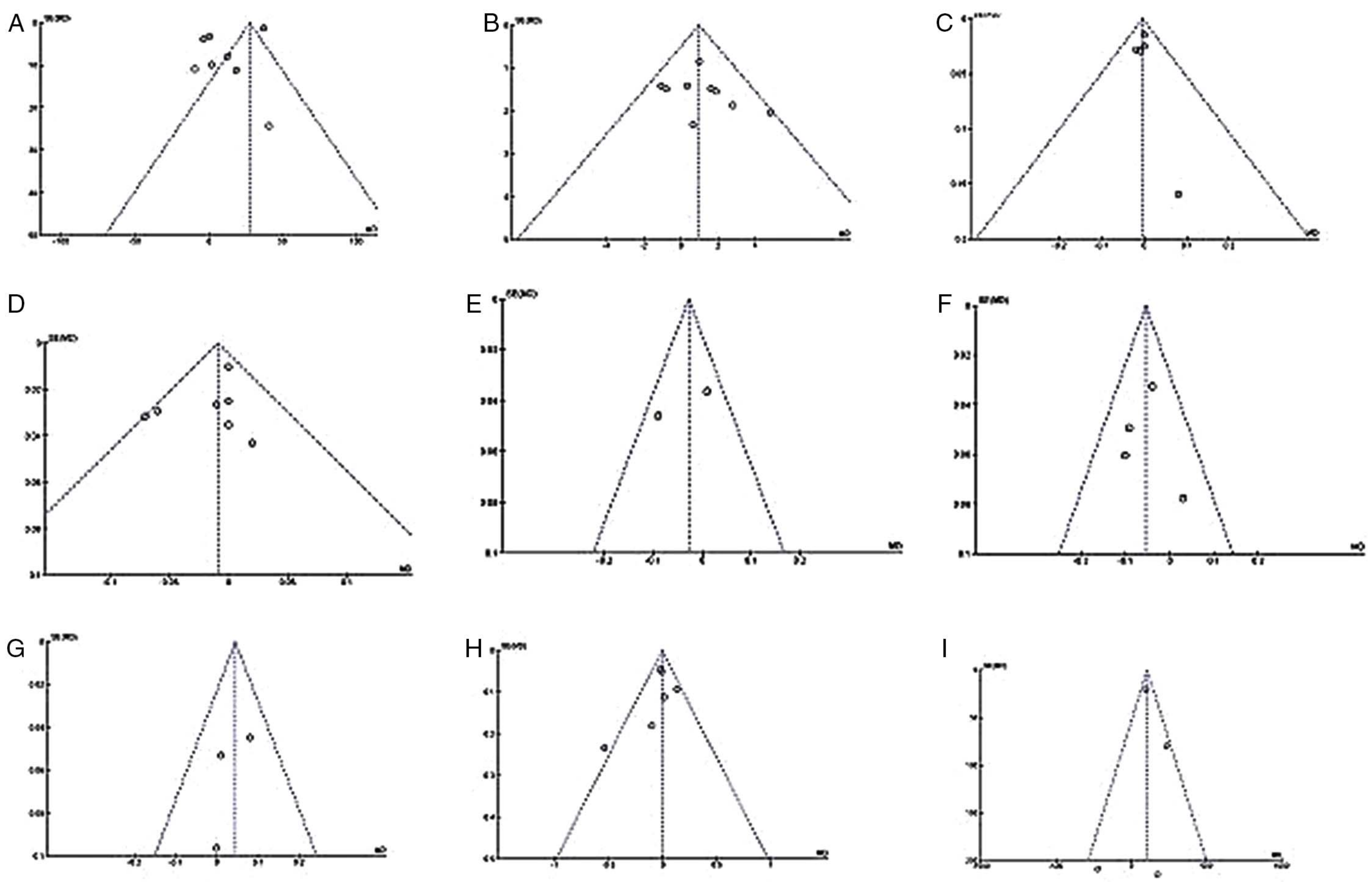


**Figure 9** — Funnel plots per outcome measure. (A) Funnel plot of strength, (B) funnel plot of countermovement jump, (C) funnel plot of 5-m sprint test, (D) funnel plot of 10-m sprint test, (E) funnel plot of 15-m sprint test, (F) funnel plot of 20-m sprint test, (G) funnel plot of 20-m sprint test, (I) funnel plot of 30-m sprint test, (H) funnel plot of agility, (I) funnel plot of endurance.

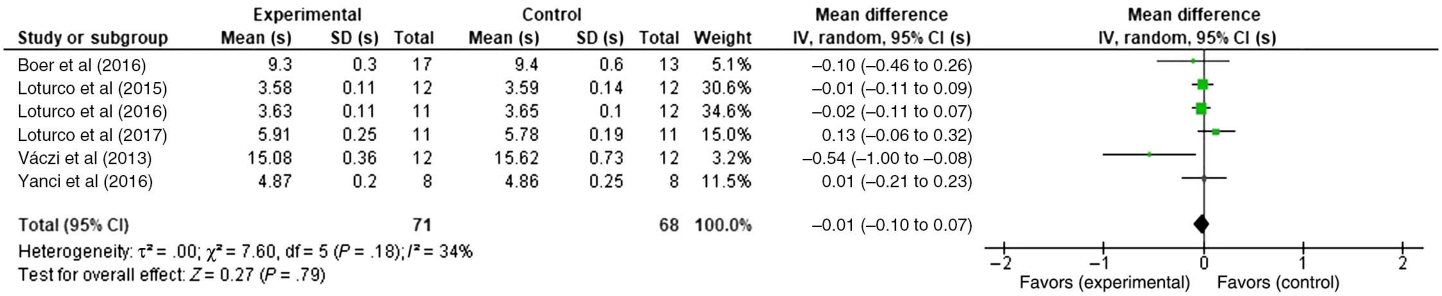


**Figure 10** — Forest plot of agility as outcome measure of plyometric training.

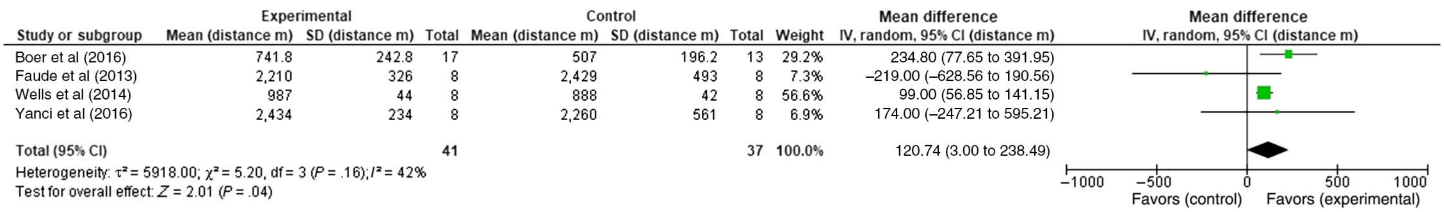


**Figure 11** — Forest plot of endurance measured with the YYIRT2 and YYIRT as outcome measure of plyometric training. YYIRT2 indicates Yo-Yo Intermittent Recovery Test 2.

## Endurance

Six studies investigated the effects of plyometric training on endurance, measured with the Yo-Yo Intermittent Recovery Test 2 (YYIRT2)[20,28,33] and the Yo-Yo Intermittent Recovery Test 1 (YYIRT)[22,34]; 1 study used an endurance running test at selected speeds.[19] Only 4 of the 6 studies reported sufficient data to allow meta-analysis. These studies show that plyometric training improves endurance, measured with YYIRT2 and YYIRT tests significantly (Figure 11).

Nakamura et al[28] found a smaller decrease in endurance during a detraining period with low-intensity plyometric training than with no training. Arcos et al[19] showed a significant improvement in endurance with 2 plyometric training programs (vertical and vertical plus horizontal exercises), with no difference between the 2 groups.

## Risk of Bias Assessment

Risk of bias assessment showed a high risk of bias in 10 of the 17 included studies. The other 7 studies scored “some concerns” in the risk of bias assessment (Table 2). The detailed results are added to Appendix B.

Funnel plots were made for each outcome, using Cochrane Review Manager 5.3. Visual interpretation suggested publication bias with regard to strength, jump height, 10-m sprint, and agility outcomes.

**Table 2 Risk of Bias Overall Judgement**

| Study | Risk of bias |
|---|---|
| Arcos et al[19] | High risk |
| Boer et al[20] | Some concerns |
| Brito et al[21] | High risk |
| Faude et al[22] | High risk |
| Jovanovic et al[23] | High risk |
| Loturco et al[24] | High risk |
| Loturco et al[25] | High risk |
| Loturco et al[26] | Some concerns |
| Loturco et al[27] | High risk |
| Mendiguchia et al[17] | Some concerns |
| Nakamura et al[28] | Some concerns |
| Rodríguez-Rosell et al[29] | Some concerns |
| Ronnestad et al[30] | High risk |
| Spineti et al[31] | High risk |
| Váczi et al[32] | Some concerns |
| Wells et al[33] | Some concerns |
| Yanci et al[34] | High risk |

Note: See Appendix B. When a study scores “+” on all subdomains, the overall judgement is “low risk of bias.” When a study scores “?” on 1 or more subdomains, the overall judgement is “some concerns.” When a study scores “–” on 1 or more subdomains or “?” on multiple subdomains that result in substantial doubt of the quality of the research, the overall judgement is “high risk of bias.”

# Discussion

This systematic review and meta-analysis focused on the effects of plyometric training on soccer-specific outcomes. There was evidence for significant benefits on jump height, 20-m sprint speed, and endurance, but an absence of evidence for positive effects on strength, sprint speed over other sprint distances, and agility tasks was found.

When interpreting the effectiveness of training programs, one should consider both the characteristics of the individuals included in the studies and the training dose that is applied. In this review, 14 out of the 17 studies included (semi)professional soccer players and 3 included amateur soccer players. Given the law of diminishing returns, effects were thus expected to be small and to depend on the training dose.[35]

The training frequency in the included studies varied from 2 to 4 times per week for 5 to 9 weeks; sessions lasted 25 to 35 minutes. The exercises were in addition to regular training sessions in all but one study.[28] The intensity and mode of the exercises varied widely. Most programs consisted of jumps with or without weights (double-legged, single-legged, and alternate-leg jumps), but also skipping or running drills. Jumps were vertical or horizontal depending on the study aims.

## Strength

We did not find plyometric training to affect strength. This was unexpected because plyometric training is known to have a positive effect on motor unit activation, changes in cross-bridge mechanics, neural efficiency, and passive tension of the muscle–tendon complex, all of which are associated with increased strength.[6,9]

One of the explanations for the absence of evidence in this review can be found in the large differences in the plyometric programs that are investigated and the interventions they are compared with. One study that compared plyometric training with strength training presented negative results, which suggests that plyometric training is subordinate to strength training for increasing strength.[31] Three studies compared 2 plyometric programs of which loads or velocity of execution were different. In these individual studies, both groups improved strength, but the comparison of mean differences between programs resulted in a small effect in this meta-analysis.[24–26] All other studies that compared plyometric training or plyometric training plus strength training with regular training resulted in increased strength.[22,29,30,32] This suggests that plyometric training can increase strength, but it depends on what type of training is already performed by the players.

Another explanation for the absence of evidence in this review can be found in the large heterogeneity between studies ($I^2 = 97\%$). For example, studies used different methods to measure strength,[3,17,21,24–26,29,30,31,32,34] and the reliability and validity of some of the tests can be questioned.[22,24–26,29,30,31,32] The outcome of functional tests, such as half squats, full squats, jump squats, and back squats, is highly dependent on the familiarity of the athlete with the exercises and the quality of performance, and not all studies reported familiarization protocols.[31,34] Only one study used the preferred reference standard, isokinetic strength testing with the Biodex system.[17] They measured concentric and eccentric strength with 60°/s. However, this study was excluded because single-leg strength was assessed, but not double-legged 1RM measurements as in the other studies.

In this systematic review and meta-analysis, no evidence was found for positive effects of plyometric training on increasing strength in soccer players. In individual studies, the largest between-group differences were found when the intensity of plyometric training was increased by increasing weight[22,29,30] or volume[32] progressively during the training period. These training programs lasted 6 to 7 weeks, for 30 minutes per session, and all exercises were vertically oriented.

## Jump Height

Plyometric training significantly improved jump height, as has also been reported for other team sports such as basketball and handball.[36–38] In these team sports, plyometric training is also known to increase strength, which, in turn, is associated with an increase in jump height during sports and rehabilitation.[39,40]

Nine studies assessed jump height by means of the CMJ, with studies comparing plyometric training with an alternative plyometric training program (N = 5), plyometric training with strength training (N = 1), or plyometric training with regular training (N = 3).

The 5 studies that compared 2 plyometric interventions compared horizontal exercises versus vertical exercises or increased velocity versus increased weight. Direction of movement and velocity or weight-guided programs probably influence training outcomes[19,24–27] and need to be considered when interpreting the effectiveness of plyometric training. Specific modifications in plyometric training programs result in adaptations in specific tasks. Thus, it is important to clearly describe not only the training program but also the training carried out by the control group. When both training programs are expected to increase jump height, the between group differences are likely to be smaller, which leads to smaller effect sizes.

Although we found plyometric training to increase jump height measured with the CMJ, the methodological limitations and risk of bias of the studies make it still questionable whether plyometric training is the best type of training to improve jump height.[41] The studies reporting a significant effect on jump height lasted 5 to 8 weeks, which means that a longer program is not necessarily more effective than a shorter program. The included studies incorporated plyometric training minimally twice a week, and 2 studies reported training sessions of 30 to 35 minutes.[22,29] It may be advised to use a combination of vertical- and horizontal-oriented jump exercises instead of only vertical jump exercises. A combination of vertical plus horizontal jump exercises seems to be more effective than solely vertical jump exercises in improving jump height.[19]

## Sprint Speed

Sprint tests over 5 distances were assessed. Plyometric training significantly increased sprint speed over 20 m but not over other distances (5, 10, 15, and 30 m). The increase in 20-m sprint speed is consistent with findings for other sports, but the absence of evidence for other distances is not.[4,9,10,42]

Plyometric training improves motor unit activation, increases joint stiffness, and increases peak torque and lower-extremity strength. Improved motor unit activation and increased joint stiffness improve acceleration,[43] and lower-extremity strength is strongly associated with maximum sprint speed.[44] Therefore, an increase in sprint speed over 20 m and longer distances would be expected. However, peak torque is also strongly associated with explosive short sprints,[8,44] and for this reason, we would have expected to find an increase in sprint speed over short distances (5–15 m). These arguments cannot explain why plyometric training did not improve sprint speed over all distances, but it is possible that sprint speed over both short and long distances require specific training methods.[5]

In the included studies, both short- and long-distance sprint speeds were evaluated after exposing players to one plyometric training program. Considering specificity of training as an important factor, one could hardly expect increased sprint speed over both short- and long-distance sprint speeds while the intervention focuses on short- or long-distance speed improvement. In order to increase soccer performance, players need to improve both short- and long-distance sprint speeds. Although the average distance of sprints in soccer is 15 m, soccer players also need to excel in sprinting over longer distances.[11] Both improving short- and long-distance sprint speeds might require specific training methods.[5,11,44,45]

Absence of evidence for increased sprint speed can also be explained by the various interventions in the control groups that limit contrast. Four of the 5 included studies in the analysis of 5-m sprint speed compared 2 plyometric programs with each other[19,25,26,34] and one study investigated the differences in effect of plyometric training versus no training in a detraining period.[28] For the 10-m sprint speed, 3 studies compared plyometric training with regular training that did not differ significantly,[22,28,30] 1 study that compared plyometric training plus strength training with regular training did significantly improve 10-m sprint speed,[29] and 3 studies compared 2 plyometric training programs.[24–26] Only 2 studies used a 15-m sprint test for evaluating sprint speed after plyometric training and both compared 2 plyometric programs and resulted in an improvement of sprint speed over 15 m, but not enough to be statistically significant different.[19,34]

Finally, the content of the training programs, in which the interventions were embedded, can be a reason for the absence of evidence. Soccer training generally consists of playing soccer, which requires players to sprint, change of direction, and jump frequently.[11,12] Adding 2 to 3 times per week 25 minutes of plyometric training might not be enough to reach overload. The results of this meta-analysis point in the direction that a plyometric program for 6 weeks, 2 times per week with sessions of 30 minutes seemed to be effective in increasing sprint speed over 20 m, but the exact training dose that is needed to gain effect is not clear yet.[25,26,29] Although the mode of exercises varied considerably, 2 studies indicated that an increase in velocity of performance of exercises was more beneficial than increasing weight or resistance of exercises.[25,26] One study added strength training to plyometric training, which resulted in a remarkable increase in sprint speed over 10 m.[29]

## Agility

We did not find plyometric training to improve the agility of male soccer players, assessed with the zigzag COD and agility *t* tests. Agility is largely correlated with sprint speed over short distances, and plyometric training is associated with short and explosive movements.[7] Thus, it would seem logical that agility would be improved by plyometric training.[4] Although acceleration and maximum sprint speed only predicted 12% and 20% of the agility performance respectively,[46] studies involving young athletes or other sports have found these exercises to improve agility.[7,47]

Nonetheless, at this point, an absence of evidence is found for effectiveness of plyometric training on agility tasks in adult male amateur soccer players. In previous studies, effects on agility performance caused by plyometric training were found, but these interventions were evaluated in tennis players, baseball players, or college students.[7] The demands on those athletes are different than those on soccer players, which implicates that their regular training sessions and their physical capacities are not comparable with soccer players. In training interventions, physical capacities at baseline and the content of regular training sessions are determining factors in effectiveness of the intervention.[41]

Absence of evidence for effects of plyometric training on agility performance is consistent with the lack of effect on sprint speed over short distances. The agility task consists of short sprints and changing direction, and we found an absence of evidence that plyometric training affected sprint speed over 5 to 15 m. Thus, at the moment, plyometric training cannot be recommended as means to improve agility.

A difficulty in the pooled analysis of the effects of plyometric training on agility is that several tests were used to measure agility. In this study, the zigzag COD and agility *t* test were included.

No advice in designing a plyometric training program can be extracted from this literature review.

## Endurance

We found plyometric training to significantly improve endurance. Endurance performance depends on aerobic and anaerobic capacity and neuromuscular factors.[48] Plyometric training aims to improve neuromuscular factors and is known to improve joint stiffness and muscle strength in players of team sports,[4,6] which, in turn, leads to improved running economy.[43,48] In addition, plyometric training has shown to decrease energy cost in running which could lead to better endurance.[49]

The results of this analysis seem contradictory with the results of the sprint speed analysis. When plyometric training only affects running economy by improving neuromuscular control, muscle strength, and joint stiffness, then both running endurance and sprint speed should be positively affected. As for all outcomes in this study, physical capacities must be mentioned as an argument. Soccer players need to have good endurance, but more importantly, it is an interval sport. In soccer, the largest part consists of walking and jogging, and a relative small part consists of sprinting.[11] Thus, the intermittent activity in plyometric training in combination with regular training might create overload and explains why soccer players improved endurance and not sprint speed over all distances.

The exact mechanism of why plyometric training benefits endurance performance remains unclear. Many factors affect endurance performance, such as maximum oxygen uptake, anaerobic work capacity, and lactate threshold.[7,48]

Only 4 studies were included in this meta-analysis, they all showed heterogeneity, and there were some concerns of bias or a high risk of bias. Therefore, the results need to be interpreted with caution.

Three of the 4 studies showed benefits of plyometric training on endurance.[20,33,34] In the study that did not report benefits of plyometric training on endurance, both groups improved endurance, but a higher postintervention score on the YYIRT2 was seen in the control group. An explanation for not finding positive results in this study can be that at baseline, the control group scored better on endurance than the intervention group.[22] In this meta-analysis, only the posttest results are included, this is based on the assumption that the groups are similar due to the randomization process (in randomized-controlled trials).

Although the results must be interpreted with caution, based on these studies, a plyometric program to improve endurance should have 2 to 3 sessions of minimally 25 minutes per week for at least 6 weeks. According to the included studies, sessions should include 360 foot contacts or 4 to 14 sets of 10 to 60 seconds duration.[20,33,34]

## Strengths and Limitations

The results of this systematic review and meta-analysis can be easily implemented in daily soccer practice, because it only included male adult soccer players. Due to field measurements and rules of the game, soccer requires tasks as sprinting over several distances, jumping, agility, and quick COD, lower-extremity strength, and endurance. This meta-analysis included all these outcomes in solely soccer players. An extensive risk of bias assessment was performed using Cochrane Robins 2.0 tool, and unfortunately, all included studies showed some concerns of bias or high risk of bias. Methodological limitations were seen in all domains of Cochrane Robins

2.0 risk of bias assessment tool. This is a major concern in training studies and hinders innovation and implementation of plyometric training.[41]

One of the limitations is that we included studies that compared plyometric training with alternative training programs, such as strength training or sprint training. This may have resulted in smaller differences in effect sizes and thus absence of evidence for most of the soccer-specific outcomes. However, an important advantage is that placebo effects can be ruled out by comparing plyometric training with other types of training. Another limitation is that plyometric training in team sports is rarely done in isolation. The amount of plyometric training in relation to regular training might make it impossible to determine the actual contribution of plyometric training on the soccer-specific outcomes.

The studies also used different tests to measure the same outcomes. Because of differences in psychometric values and test protocols, pooling of these results was not always possible, and some studies were excluded from the meta-analysis.

Finally, although meta-regression analysis could have been performed to correct for the heterogeneity of the data, we chose not to do this because of possible bias and outcomes of the analysis. Concerns about the risk of bias and the low to moderate quality of the included studies mean that the generalizability and possibilities to implement the results of the meta-analysis are limited.

### Future Research

Methodological quality should improve in future studies focusing on the effects of plyometric training on outcomes related to soccer performance. Studies should include a clear description of the randomization process, the intervention, and the control group. Furthermore, consensus about how results should be presented is needed, with minimally player characteristics and postintervention means and SDs being reported.

Second, research should focus on differences in effects of plyometric exercise modes for soccer-specific outcomes and on investigating which training loads result in the largest response. Furthermore, research should differentiate between vertical and horizontal plyometric exercises and investigate which direction (or combination of directions) is more effective for a specific task.

Another aspect worth investigating is whether plyometric training should be incorporated in injury prevention strategies. The combination of physiological and biomechanical changes caused by plyometric training and possible performance enhancement might make plyometric training suitable for injury prevention strategies and make it easier to implement injury prevention programs in daily soccer practice.

## Practical Applications

Coaches and practitioners can use plyometric training for increasing jump height, increasing sprint speed over 20 m, and improving endurance. The key points in designing plyometric training programs were that effective programs consisted of 2 to 3 sessions per week of 25 to 35 minutes each, for a period of at least 6 weeks. In addition, horizontal- and vertical-oriented exercises are advised as well as an increase in velocity of performance instead of an increase in weight of the plyometric exercises. Whether these improvements actually contribute to match performance remains unclear. Based on this systematic review and meta-analysis, plyometric training is not advised to use for increasing strength, 5-, 10-, 15-, and 30-m sprint speed and improve agility in soccer players.

## Conclusion

This review and meta-analysis showed that plyometric training can improve jump height, 20-m sprint speed (but not over other distances), and endurance in male adult soccer players. However, the low quality of the included studies and the substantial heterogeneity mean that these findings should be interpreted with caution. An absence of evidence for positive effects of plyometric training on strength, 5-, 10-, and 30-m sprints and agility was found.

There is a lack of high-quality studies investigating the effects of plyometric training on soccer-specific outcomes. Future research should be of high methodological quality and clearly describe the randomization process, design, and intensity of the programs, and report postintervention means and SDs and preferably effect sizes. This high-quality research should indicate whether or not plyometric training can be used for performance enhancement.

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## References

1. Stølen T, Chamari K, Castagna C, Wisløff U. Physiology of soccer: an update. *Sport Med*. 2005;35(6):501–536. doi:10.2165/00007256-200535060-00004
2. Barnes C, Archer DT, Hogg B, Bush M, Bradley PS. The evolution of physical and technical performance parameters in the English premier league. *Int J Sports Med*. 2014;39:1–11. doi:10.1055/s-0034-1375695
3. Faude O, Koch T, Meyer T. Straight sprinting is the most frequent action in goal situations in professional football. *J Sports Sci*. 2012; 30(7):625–631. PubMed ID: 22394328 doi:10.1080/02640414.2012.665940
4. Davies G, Riemann BL, Manske R. Current concepts of plyometric exercise. *Int J Sports Phys Ther*. 2015;10(6):760–786. PubMed ID: 26618058 doi:10.1080/00754170500221345
5. Sale DG. Neural adaptation to resistance training. *Med Sci Sports Exerc*. 1988;20(5 Suppl):S135–S145. PubMed ID: 3057313 doi:10.1249/00005768-198810001-00009
6. Ramírez-Campillo R, Burgos CH, Henríquez-Olguín C, et al. Effect of unilateral, bilateral, and combined plyometric training on explosive and endurance performance of young soccer players. *J Strength Cond Res*. 2015;29(5):1317–1328. doi:10.1519/JSC.0000000000000762
7. Markovic G, Mikulic P. Neuro-musculoskeletal and performance adaptations to lower-extremity plyometric training. *Sport Med*. 2010; 40(10):859–895. doi:10.2165/11318370-000000000-00000
8. Young W, McLean B, Ardagna J. Relationship between strength qualities and sprinting performance. *J Sports Med Phys Fitness*. 1995; 35(1):13–19. PubMed ID: 7474987 doi:10.1201/b10132-109
9. Malisoux L. Stretch-shortening cycle exercises: an effective training paradigm to enhance power output of human single muscle fibers. *J Appl Physiol*. 2005;100(3):771–779. PubMed ID: 16322375 doi:10.1152/japplphysiol.01027.2005
10. Slimani M, Chamari K, Miarka B, Del Vecchio FB, Chéour F. Effects of plyometric training on physical fitness in team sport athletes: a systematic review. *J Hum Kinet*. 2016;53:231–247. PubMed ID: 28149427 doi:10.1515/hukin-2016-0026

11. Taylor JB, Wright AA, Dischiavi SL, Townsend MA, Marmon AR. Activity demands during multi-directional team sports: a systematic review. *Sport Med*. 2017;47(12):2533–2551. doi:10.1007/s40279-017-0772-5
12. Varley MC, Gabbett T, Aughey RJ. Activity profiles of professional soccer, rugby league and Australian football match play. *J Sports Sci*. 2014;32(20):1858–1866. PubMed ID: 24016304 doi:10.1080/02640414.2013.823227
13. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *J Clin Epidemiol*. 2009;62(10):1006–1012. PubMed ID: 19631508 doi:10.1016/j.jclinepi.2009.06.005
14. Booth A, Clarke M, Dooley G, et al. The nuts and bolts of PROSPERO: an international prospective register of systematic reviews. *Syst Rev*. 2012;1:2. PubMed ID: 22587842 doi:10.1186/2046-4053-1-2
15. Higgins J, Sterne J, Savović J, et al. A revised tool for assessing risk of bias in randomized trials. In: Cochrane Methods. *Cochrane Database Syst Rev*. 2016;10(suppl 1):29–31. doi:10.1002/14651858.CD201601
16. Cochrane TC. Review Manager (RevMan) 5.3. *Copenhagen Nord Cochrane Cent*. 2008.
17. Mendiguchia J, Martinez-Ruiz E, Morin JB, et al. Effects of hamstring-emphasized neuromuscular training on strength and sprinting mechanics in football players. *Scand J Med Sci Sport*. 2015;25(6):e621–e629. doi:10.1111/sms.12388
18. Landis JR, Koch GG. The measurement of observer agreement for categorical data. *Biometrics*. 1977;33(1):159–174. PubMed ID: 843571 doi:10.2307/2529310
19. Arcos AL, Yanci J, Mendiguchia J, Salinero JJ, Brughelli M, Castagna C. Short-term training effects of vertically and horizontally oriented exercises on neuromuscular performance in professional soccer players. *Int J Sports Physiol Perform*. 2014;9(3):480–488. PubMed ID: 23579053 doi:10.1123/ijspp.2013-0063
20. Boer PH, Van Aswegen M. Effect of combined versus repeated sprint training on physical parameters in sub-elite football players in South Africa. *J Phys Educ Sport*. 2016;16(3):964–971. doi:10.7752/jpes.2016.03152
21. Brito J, Vasconcellos F, Oliveira J, Krustrup P, Rebelo A. Short-term performance effects of three different low-volume strength-training programmes in college male soccer players. *J Hum Kinet*. 2014;40:121–128. PubMed ID: 25031680 doi:10.2478/hukin-2014-0014
22. Faude O, Roth R, Di Giovine D, Zahner L, Donath L. Combined strength and power training in high-level amateur football during the competitive season: a randomised-controlled trial. *J Sports Sci*. 2013;31(13):1460–1467. PubMed ID: 23768214 doi:10.1080/02640414.2013.796065
23. Jovanovic M, Sporis G, Omrcen D, Fiorentini F. Effects of speed, agility, quickness training method on power performance in elite soccer players. *J Strength Cond Res*. 2011;25(5):1285–1292. PubMed ID: 21522073 doi:10.1519/JSC.0b013e3181d67c65
24. Loturco I, Ugrinowitsch C, Tricoli V, Pivetti B, Roschel H. Different loading schemes in power training during the preseason promote similar performance improvements in Brazilian elite soccer players. *J Strength Cond Res*. 2013;27(7):1791–1797. PubMed ID: 23085970 doi:10.1519/JSC.0b013e3182772da6
25. Loturco I, Nakamura FY, Kobal R, et al. Training for power and speed: effects of increasing or decreasing jump squat velocity in elite young soccer players. *J Strength Cond Res*. 2015;29(10):2771–2779. PubMed ID: 25807028 doi:10.1519/JSC.0000000000000951
26. Loturco I, Nakamura FY, Kobal R, et al. Traditional periodization versus optimum training load applied to soccer players: effects on neuromuscular abilities. *Int J Sports Med*. 2016;37(13):1051–1059. PubMed ID: 27706551 doi:10.1055/s-0042-107249
27. Loturco I, Kobal R, Kitamura K, et al. Mixed training methods: effects of combining resisted sprints or plyometrics with optimum power loads on sprint and agility performance in professional soccer players. *Front Physiol*. 2017;8:1034. PubMed ID: 29311968 doi:10.3389/fphys.2017.01034
28. Nakamura D, Suzuki T, Yasumatsu M, Akimoto T. Moderate running and plyometric training during off-season did not show a significant difference on soccer-related high-intensity performances compared with no-training controls. *J Strength Cond Res*. 2012;26(12):3392–3397. PubMed ID: 22207263 doi:10.1519/JSC.0b013e3182474356
29. Rodríguez-Rosell D, Torres-Torrelo J, Franco-Márquez F, González-Suárez JM, González-Badillo JJ. Effects of light-load maximal lifting velocity weight training vs combined weight training and plyometrics on sprint, vertical jump and strength performance in adult soccer players. *J Sci Med Sport*. 2017;20(7):695–699. doi:10.1016/j.jsams.2016.11.010
30. Ronnestad BR, Kvamme NH, Sunde A, Raastad T. Short-term effects of strength and plyometric training on sprint and jump performance in professional soccer players. *J Strength Cond Res*. 2008;22(3):773–780. PubMed ID: 18438241 doi:10.1519/JSC.0b013e31816a5e86
31. Spineti J, Figueiredo T, de Oliveira VB, et al. Comparison between traditional strength training and complex contrast training on repeated-shuttle-sprint ability and muscle architecture in male elite soccer players. *J Sports Med Phys Fitness*. 2015;56(11):1269–1278. PubMed ID: 26609969 doi:10.23736/S0022-4707.18.07934-3
32. Váczi M, Tollár J, Meszler B, Juhász I, Karsai I. Short-term high intensity plyometric training program improves strength, power and agility in male soccer players. *J Hum Kinet*. 2013;36:17–26. doi:10.2478/hukin-2013-0002
33. Wells C, Edwards A, Fysh M, Drust B. Effects of high-intensity running training on soccer-specific fitness in professional male players. *Appl Physiol Nutr Metab*. 2014;39(7):763–769. PubMed ID: 24971676 doi:10.1139/apnm-2013-0199
34. Yanci J, Los Arcos A, Camara J, Castillo D, García A, Castagna C. Effects of horizontal plyometric training volume on soccer players' performance. *Res Sport Med*. 2016;24(4):308–319. doi:10.1080/15438627.2016.1222280
35. American College of Sports Medicine. *ACSM Guidelines for Exercise Testing and Prescription*. Philadelphia, PA: Wolters Kluwer Health/Lippincott Williams & Wilkins; 2014. doi:10.1007/s13398-014-0173-7.2
36. Markovic G. Does plyometric training improve vertical jump height? A meta-analytical review. *Br J Sports Med*. 2007;41(6):349–355. PubMed ID: 17347316 doi:10.1136/bjsm.2007.035113
37. Latorre Román PÁ, Villar Macias FJ, García Pinillos F. Effects of a contrast training programme on jumping, sprinting and agility performance of prepubertal basketball players. *J Sports Sci*. 2018;36(7):802–808. doi:10.1080/02640414.2017.1340662
38. Chelly MS, Hermassi S, Aouadi R, Shephard RJ. Effects of 8-week in-season plyometric training on upper and lower limb performance of elite adolescent handball players. *J Strength Cond Res*. 2014;28(5):1401–1410. PubMed ID: 24149768 doi:10.1519/JSC.0000000000000279
39. Alemdaroğlu U. The relationship between muscle strength, anaerobic performance, agility, sprint ability and vertical jump performance in professional basketball players. *J Hum Kinet*. 2012;31:149–158. doi:10.2478/v10078-012-0016-6

40. Laudner K, Evans D, Wong R, et al. Relationship between isokinetic knee strength and jump characteristics following anterior cruciate ligament reconstruction. *Int J Sports Phys Ther*. 2015;10(3):272–280. PubMed ID: 26075142 doi:10.2519/jospt.1998.28.1.23
41. Ramirez-Campillo R, Álvarez C, García-Hermoso A, et al. Methodological characteristics and future directions for plyometric jump training research: a scoping review. *Sport Med*. 2018;48(5):1059–1081. doi:10.1007/s40279-018-0870-z
42. Bedoya AA, Miltenberger MR, Lopez RM. Plyometric training effects on athletic performance in youth soccer athletes: a systematic review. *J Strength Cond Res*. 2015;29(8):2351–2360. PubMed ID: 25756326 doi:10.1519/JSC.0000000000000877
43. Kyrolainen H, Belli A, Komi PV. Biomechanical factors affecting running economy. *Med Sci Sports Exerc*. 2001;33(8):1330–1337. PubMed ID: 11474335 doi:10.1097/00005768-200108000-00014
44. Young W, Benton D, Duthie G, Pryor J. Resistance training for short sprints and maximum-speed sprints. *Strength Cond J*. 2001;23(2):7–13. doi:10.1519/00126548-200104000-00001
45. Rebelo ANC, Silva P, Rago V, Barreira D, Krustrup P. Differences in strength and speed demands between 4v4 and 8v8 small-sided football games. *J Sports Sci*. 2016;34(24):2246–2254. PubMed ID: 27278256 doi:10.1080/02640414.2016.1194527
46. Little T, Williams AG. Specificity of acceleration, maximum speed, and agility in professional soccer players. *J Strength Cond Res*. 2005;19(1):76–78. PubMed ID: 15705049 doi:10.1519/14253.1
47. Keller S, Koob A, Corak D, von Schöning V, Born D-P. How to improve change-of-direction speed in junior team sport athletes-horizontal, vertical, maximal, or explosive strength training? [published online ahead of print September 07, 2018]. *J strength Cond Res*. doi:10.1519/JSC.0000000000002814
48. Coyle EF. Integration of the physiological factors determining endurance performance ability. *Exerc Sport Sci Rev*. 1995;23:25–63. PubMed ID: 7556353 doi:10.1249/00003677-199500230-00004
49. Lacour JR, Bourdin M. Factors affecting the energy cost of level running at submaximal speed. *Eur J Appl Physiol*. 2015;115(4):651–673. PubMed ID: 25681108 doi:10.1007/s00421-015-3115-y

# Appendix A: Search String Pubmed

(((((((Soccer[MeSH Terms]) OR Football[MeSH Terms]) OR soccer[Title/Abstract]) OR football[Title/Abstract]) AND male [Title/Abstract])) AND ((((((((((((((((((exercise, plyometric [MeSH Terms]) OR exercises, plyometric[MeSH Terms]) OR plyometric exercise[MeSH Terms]) OR plyometric exercises [MeSH Terms]) OR plyometric training[MeSH Terms]) OR plyometric exercise*[Title/Abstract]) OR plyometric training [Title/Abstract]) OR Plyometry[Title/Abstract]) OR Bounding [Title/Abstract]) OR Bounding exercise[Title/Abstract]) OR alternate bounding[Title/Abstract]) OR alternate leg bounding[Title/Abstract]) OR jumping[Title/Abstract]) OR jump training[Title/Abstract]) OR jump exercises[Title/Abstract]) OR jumping exercises[Title/Abstract]) OR sprint training[Title/Abstract]) OR running exercises[Title/Abstract])) AND (((((((((((((((((((((((((((((((((((((((((((((((((((((((((((((((((((((((muscle strength[MeSH Terms]) OR muscle contraction[MeSH Terms]) OR muscle contractions[MeSH Terms]) OR athletic performance[MeSH Terms]) OR athletic performances[MeSH Terms]) OR muscle strength[Title/Abstract]) OR muscle contraction[Title/Abstract]) OR athletic performance [Title/Abstract]) OR muscle contractions[Title/Abstract]) OR athletic performances[Title/Abstract]) OR Sprint[Title/Abstract]) OR sprint speed[Title/Abstract]) OR sprinting[Title/Abstract]) OR horizontal speed[Title/Abstract]) OR horizontal sprinting[Title/Abstract]) OR sprint performance[Title/Abstract]) OR sprint velocity[Title/Abstract]) OR sprint time[Title/Abstract]) OR 5m sprint[Title/Abstract]) OR 10m sprint[Title/Abstract]) OR agility t-test[Title/Abstract]) OR sprint test[Title/Abstract]) OR repeated sprint ability test[Title/Abstract]) OR Horizontal jump[Title/Abstract]) OR Horizontal jump distance[Title/Abstract]) OR Horizontal jumping[Title/Abstract]) OR jump distance[Title/Abstract]) OR Vertical jump[Title/Abstract]) OR Vertical jumping [Title/Abstract]) OR Jump height[Title/Abstract]) OR standing long jump[Title/Abstract]) OR squat jump[Title/Abstract]) OR jump squat[Title/Abstract]) OR single leg vertical jump[Title/Abstract]) OR triple hop for distance[Title/Abstract]) OR alternate leg hop[Title/Abstract]) OR countermovement jump[Title/Abstract]) OR drop jump[Title/Abstract]) OR 6 meter timed hop [Title/Abstract]) OR muscular performance[Title/Abstract]) OR physical conditioning[Title/Abstract]) OR performance[Title/Abstract]) OR stretch-shortening-cycle[Title/Abstract]) OR stretch-shortening cycle[Title/Abstract]) OR change of direction[Title/Abstract]) OR Eccentric strength[Title/Abstract]) OR Isokinetic strength[Title/Abstract]) OR concentric strength[Title/Abstract]) OR H : Q ratio[Title/Abstract]) OR hamstring- quadriceps ratio [Title/Abstract]) OR muscle activation pattern[Title/Abstract]) OR Early preactivation[Title/Abstract]) OR preparatory activity[Title/Abstract]) OR reactive activity[Title/Abstract]) OR Greater amplitude[Titl0e/Abstract]) OR Increased co-activation[Title/Abstract]) OR Peak vertical impact force[Title/Abstract]) OR Rate of Force development[Title/Abstract]) OR Joint excursion[Title/Abstract]) OR Postural control[Title/Abstract]) OR landing accuracy[Title/Abstract]) OR EMG[Title/Abstract]) OR Star excursion balance test[Title/Abstract]) OR Landing error scoring system[Title/Abstract]) OR Limb symmetry index[Title/Abstract]) OR stability [Title/Abstract]) OR active stability[Title/Abstract]) OR neuromuscular control[Title/Abstract]) OR neuromuscular performance [Title/Abstract])

# Appendix B: Risk of Bias Assessment With Cochrane Robins 2.0

| Study | Random sequence generation | Allocation concealment | Blinding of participants and personnel | Incomplete outcome data | Blinding of outcome | Selective reporting | Overall judgment |
|---|---|---|---|---|---|---|---|
| Arcos et al (2014) | ? | ? | − | + | + | + | − |
| Boer et al (2016) | ? | ? | ? | ? | ? | ? | ? |
| Brito et al (2014) | ? | − | − | + | + | + | − |
| Faude et al (2012) | ? | − | − | + | + | + | − |
| Jovanovic et al (2011) | ? | ? | − | + | + | − | − |
| Loturco et al (2013) | ? | ? | − | + | + | + | − |
| Loturco et al (2015) | ? | ? | − | + | + | + | − |
| Loturco et al (2016) | ? | ? | + | + | + | + | ? |
| Loturco et al (2017) | ? | − | + | + | + | + | − |
| Mendiguchia et al (2015) | ? | ? | ? | ? | ? | ? | ? |
| Nakamura et al (2012) | ? | ? | ? | ? | ? | ? | ? |
| Rodríguez-Rosell et al (2017) | ? | ? | + | + | + | + | ? |
| Ronnestad et al (2008) | ? | ? | + | + | + | − | − |
| Spineti et al (2015) | ? | ? | + | − | + | + | − |
| Váczi et al (2013) | ? | ? | + | + | + | + | ? |
| Wells et al (2014) | ? | ? | + | + | + | + | ? |
| Yanci et al (2016) | ? | ? | + | − | + | + | − |

Note: +, Low risk of bias; ?, some concerns for risk of bias; −, high risk of bias.