MURPHY, A., BURGESS, K., HALL, A.J., ASPE, R.R. and SWINTON, P.A. 2023. The effects of strength and conditioning interventions on sprinting performance in team sport athletes: a systematic review and meta-analysis. *Journal of strength and conditioning research* [online], 37(8), pages 1692-1702. Available from: https://doi.org/10.1519/JSC.0000000000004440

# The effects of strength and conditioning interventions on sprinting performance in team sport athletes: a systematic review and meta-analysis.

MURPHY, A., BURGESS, K., HALL, A.J., ASPE, R.R. and SWINTON, P.A.

2023

*This is a non-final version of an article published in final form in MURPHY, A., BURGESS, K., HALL, A.J., ASPE, R.R. and SWINTON, P.A. 2023. The effects of strength and conditioning interventions on sprinting performance in team sport athletes: a systematic review and meta-analysis. Journal of strength and conditioning research, 37(8), pages 1692-1702. Available from: https://doi.org/10.1519/JSC.0000000000004440*
*Supplementary materials are appended after the main text of this document.*

OpenAIR @RGU

This document was downloaded from https://openair.rgu.ac.uk

BY NC

# The effects of strength and conditioning interventions on sprinting performance in team sport athletes: A systematic review and meta-analysis

**Brief Title: S&C for team athlete sprinting**

**Andrew, Murphy[1]. Katherine, Burgess[1]. Andy, J. Hall[1]. Rodrigo, R. Aspe[1]. Paul, A. Swinton[1*]**

**Institution**

[1] School of Health Sciences, Robert Gordon University, Aberdeen, United Kingdom.

*** Corresponding Author**

**Dr. Paul Swinton**

**School of Health Sciences, Robert Gordon University**

**Garthdee Road**

**Aberdeen, UK,**

**AB10 7QG**

**p.swinton@rgu.ac.uk, +44 (0) 1224 262 3361**

## Abstract

Linear sprinting is a key determinant of athletic performance within team sports. The aims of the review were to quantify and compare the effectiveness of popular strength and conditioning (S&C) training modes to improve sprint performance in team sport athletes, with additional focus on potential moderators and the relationships between improvements in physical factors (e.g. strength, power and jump performance) and improvements in sprint performance. Inclusion was restricted to resistance, plyometric, sprint and combined training interventions comprising team sport athletes. Multi-level, Bayesian meta-analysis and meta-regression models conducted with standardised mean difference effect sizes were used to investigate training modes and potential moderators. Weighted regression models conducted on shrunken estimates from initial Bayesian meta-analyses were used to quantify relationships between improvements in physical factors and improvements in sprint performance. Certainty of evidence was assessed using the Grading of Recommendations Assessment Development and Evaluation (GRADE) approach. Similar improvements in sprint performance were obtained across training modes, with some evidence of the largest effects with resistance training ($\mathrm{SMD}_{\mathrm{Pre}_{0.5}}$=0.55 [95%CrI:0.36-0.78; very low certainty]). A strong moderating effect of training intensity was identified across all training modes with evidence of greater improvements in sprint performance with high intensity training ($\beta_{\mathrm{Low:High}_{0.5}}$=0.17 [95%CrI:0.01-0.33; very low certainty]). Strong positive relationships were identified between improvements in all physical factors and sprint performance ($\beta_{\mathrm{Strength}_{0.5}}$=0.56 [95%CrI:0.36-0.77; low certainty], $\beta_{\mathrm{Power}_{0.5}}$=0.80 [95%CrI:0.50-1.0; low certainty], $\beta_{\mathrm{Jump}_{0.5}}$=0.78 [95%CrI:0.57-0.97; low certainty]). The findings indicate that focus on developing speed in team sport athletes should be placed on S&C training with high intensities, including the use of resisted sprint training.

Key words: S&C; Strength; Power; Specificity; Transfer; Bayesian

## Introduction

Strength and conditioning (S&C) is frequently used with athletes to enhance athletic performance and reduce injury risk. Research has consistently demonstrated that engagement in S&C training modes such as resistance exercise increases the ability to express force and power during resisted movements (1-3). However, the ability to improve athletic performance is also dependent on the magnitude of transfer between training adaptations and desired performance outcomes (4). Long-term performance adaptations and the transfer of training are dependent on the principles of overload and specificity (3, 5, 6), with the magnitude of adaptations influenced primarily by overload and the amount of transfer influenced primarily by the degree of specificity with target outcomes. The principle of specificity generally considers the kinematic and kinetic similarities between S&C training and the targeted sporting outcomes and actions (7, 8). For example, resisted sprint training comprises a high degree of specificity with sprint performance, and is frequently referred to in this context as a "direct training" method. In contrast, traditional resistance training comprises low specificity with regards to sprint performance and can therefore be considered in this context an "indirect training" method.

It has been identified that overload and specificity can be conflicting with greater overload of an exercise reducing specificity and vice versa (8). Multiple theoretical models have been developed by practitioners to describe transfer of training, however, research has predominantly focussed on empirical models quantifying correlations between sporting actions and kinematic and kinetic variables collected during performance of S&C exercises (9-12). Frequently this correlational research has included athletes participating in teams sport where actions such as linear sprinting are performed regularly and have been shown to be a key determinant of athletic performance (13-18). Correlational research conducted specifically with team sport athletes had consistently demonstrated that lower-body maximum strength and power output scaled relative to body mass produced moderate to strong correlations with sprinting performance (19-23). Baker and Nance (19) and McBride et al. (21) reported comparable correlations between scaled lower-body strength and 10 and 40 m sprint performance. Conversely, more recent studies from Cunningham et al. (23) and Furlong et al. (24) reported low and non-significant correlations between relative strength and maximum velocity sprinting over 30 m. However, the authors did report moderate to strong correlations between measures of jump height, reactive strength index, lower limb stiffness and maximum velocity sprinting. These more recent results suggest that relationships between measures of physical capacity and sprinting may be different through the acceleration and maximum velocity phases.

Maximum effort sprinting commonly occurs over short distances (<30 m) and durations (2-3 s) in team sports, therefore S&C training and subsequent longitudinal research has emphasised development of speed and acceleration over similar distances (16, 25, 26). Previous intervention studies have reported reductions in sprint times of 0.03-0.41 s across a range of athletes and distances up to 40 m, with an average percentage difference of 3-4% (15, 27-35). Training status and mode of training have been identified as potential moderators (36, 37) with researchers suggesting more experienced athletes require training modes with high levels of specificity for continued improvement in sprinting performance (7). As a result, a range of training modes have been developed in attempts to maximise production of kinetic variables associated with sprinting performance to maximise transfer of training. The most common modes include resistance training, ballistic resistance training, plyometric training, combined training methods featuring both resistance and plyometric modes, as well as sprint specific training methods (e.g. resisted, free sprinting and assisted/overspeed). Given the broad range of training modes and the likely existence of other moderating factors including training status and specific training dose (e.g.

frequency, volume and intensity), identification of the most effective S&C training interventions to improve sprinting performance remains challenging.

Multiple narrative reviews and systematic reviews combined with meta-analyses (36-47) have been conducted to synthesise research investigating S&C training and sprinting performance. Reviews from Bolger et al. (40) and Haugen et al. (38) focussed on training methods to improve sprint performance in elite track and field sprinters. Bolger et al. (40) and Haugen et al. (38) suggested that both direct and indirect training modes may produce positive adaptations with elite sprinters; however, both reviews identified the need for further research. Employing meta-analytic techniques, Rumpf et al. (39) compared effect sizes for direct and indirect training modes across a range of sprint distances in physically active team and non-team sport athletes. The authors reported moderate to large effects on sprint performance following sprint specific training, with resisted sprint training producing the largest effect on distances of 0-20 m and free sprinting producing the greatest effects at distances over 31 m. In contrast, indirect training modes including resistance and plyometrics produced only small to moderate effects. Recently, two large scale meta-analyses' including 121 and 86 studies compared the effectiveness of multiple training modes on acceleration (46) and maximum velocity (47) with football code athletes competing in sports such as soccer, American football, Canadian football, Australian football, Gaelic football, and rugby. The authors' concluded that combined specific and non-specific training modes, focussing on the development of physical capacity in conjunction with high specificity sprint training in the form of resisted sprinting produced the largest effects during the acceleration phase. In contrast, non-specific training methods were shown to produce the greatest improvements in maximum velocity performance within the same population. Whilst recent meta-analyses have begun to provide clearer results regarding the relative effectiveness of different training modes in the development of sprint performance in team sport population, there remains limited understanding of the potential moderating role of programme variables such as training intensity and volume. To the authors' knowledge, there is no meta-analysis to date has attempted to model relationships between changes in strength and power and subsequent changes in sprint performance in team sport athletes. Given the availability of previous data and a lack of large-scale modelling research investigating some of the more complex relationships between S&C training and sprint performance in team sport athletes, the purpose of this systematic review and meta-analysis was to: 1) synthesise and compare effect sizes of different S&C training modes on sprint performance; 2) investigate the effect of potential moderators including athlete level, training duration, frequency, intensity and volume; and 3) investigate the relationships between improvements in standard S&C training outcomes such as strength and power and improvements in sprint performance.

## Methods

### Overview:

The current systematic review and meta-analysis comprised a comprehensive synthesis quantifying effectiveness of S&C training on sprinting performance of team sport athletes. Primary analyses investigated the effects of potential moderators including athlete demographics (e.g. training type and training level) and training dose parameters (e.g. frequency, volume and intensity). Secondary analyses investigated relationships between changes in standard S&C training outcomes such as strength and power and improvements in sprint performance. The methods used in the systematic review adhered to an a-priori protocol (3) and previously published guidelines including the checklist of Preferred Reporting items for Systematic Review and Meta-Analysis Protocols (PRISMA-P) (48) which is presented in the supplementary files (SF-1).

### Eligibility Criteria:

The PICOS (Population, Intervention, Comparator, Outcomes and Study Design) approach was used to guide determination of eligibility criteria for this review.

*Population:*

Healthy males and females aged 16 and over participating in a team sport at any level and of any training status were considered for inclusion in this review. Participant age was restricted to reduce any pre-post difference in sprint performance that may be due to changes in the early biological maturation status occurring during the intervention period (49, 50). Additionally, it has been suggested that S&C interventions may become more targeted towards sport specific outcomes (e.g. sprint performance) in later adolescence potentially through inclusion in performance academies and other high-level sporting environments (49).

*Intervention:*

Longitudinal studies comprising S&C interventions of at least 4 weeks in duration that could be categorised as an indirect or direct (definitions provided in table 1) sprint training mode were included. A minimum duration of 4 weeks was selected as it is considered the shortest period required to elicit measurable adaptations from S&C training interventions and considered a common unit of time to describe a single training block (51, 52). Lower-body strength and power are regarded as important factors in determining sprint performance of team sport athletes (22) and therefore inclusion was restricted to interventions that targeted development of the gluteals, quadriceps, hamstrings, gastrocnemius, and soleus.

*Comparator:*

Both controlled and non-controlled study designs were included with non-controlled effect sizes used for analyses. Where studies include comparators that did not meet inclusion criteria, only group data that matched the criteria were included.

*Outcomes and Prioritisation:*

The primary outcomes for the review included sprint time (s) and sprint velocity ($m.s^{-1}$). Sprint outcomes were included across all distances, with subset-analyses performed on sprint outcomes up to 40 m separated into 10 m intervals (36, 37). Secondary outcomes included measures of lower-body strength and power. Measures of strength were restricted to those assessing maximum force production (e.g. 1RM and isometric mid-thigh pull), and measures of power included both indirect (e.g. vertical jump height) and direct assessments measured in Watts collected during performance of a lower-body resisted or non-resistance movement (e.g. leg press, squat, squat jump or appropriate cycle ergometer assessment). These secondary outcomes were used to assess the relationship between improvements in strength and power and subsequent improvements in sprinting performance. Given the modelling focus of this review and attempts to quantitatively explore moderators and relationships among outcomes, only studies that included sufficient data including pre/post means and standard deviations or standard errors, along with specific information of moderating factors such as intervention intensity, volume, exercises included and frequency, to be incorporated in meta-analyses were included.

Table 1: Definitions of indirect and direct training modes used for review.

| **Training Mode** | **Definition** |
|---|---|
| *Indirect training modes:* | |
| Standard resistance | Multi-joint exercise (e.g. squat or deadlift) performed on a flat, stable surface with bodyweight, free weights or machines in which it is possible to replicate lower-body multi-joint exercises (e.g. smith machine and hack squat). |
| Ballistic resistance | Exercise performed at maximum intent with the projection of an external load at moderate to high velocity (e.g. Olympic weightlifting and loaded jump squats). |
| Plyometric training | Exercises which utilise the stretch shortening cycle with rapid transition of eccentric to concentric contraction phases to produce high velocity movements resulting in jump or bound. |
| *Direct training modes:* | |
| Free sprint training | Maximum intent sprinting performed on a flat, stable surface without any external resistance or assistance. |
| Resisted sprint training | Maximum intent sprinting performed on a stable surface against an external resistance with the use of a sled, wearable resistance or incline with the aim to decrease maximum achievable velocity and increase kinetic output. |
| Assisted sprint training | Maximum intent sprinting performed with assistance in the form of a pulley, towing or bodyweight reduction harness with the aim to improve certain sprint kinematics, namely achieve supramaximum velocities. |
| *Combined training modes:* | |
| Combined training | Combinations of resistance, sprint, ballistic and/or plyometric training. To be considered a combined training mode, the secondary mode must account for at least 30% of total lower body training volume (number of lower body exercises multiplied by averages number of sets completed multiplied by average number of repetitions completed will be used to calculate training volume). If indirect combined with sprint training, more than 5+ sets must be completed, and/or >= 100m in sprinting must be completed within the training week. |

**Search Strategy:**

The search strategy used for this study was part of a larger search conducted to investigate the distribution of effect sizes across most of the S&C literature (3). The search was performed using Embase, Medline, Web of Science, Sport Discus and Google Scholar. Hand searching of relevant journals including Medicine and Science in Sports and Exercise, the J Strength Cond Res, and Research Quarterly was also conducted. Database search terms were included to identify various training modes, longitudinal interventions, and a range of outcome measures. The following keywords and phrases were combined with Boolean operators; "strength" OR "resistance" OR "sprint" OR "plyometric" OR "exercise" AND "intervention" OR "training" OR "program" OR "programme" AND "1RM" OR "repetition maximum" OR "speed" OR "velocity" OR "power" OR "jump" OR "change of direction" OR "agility" OR "acceleration" OR "rate of force development". No restriction was placed on the date of the study. The initial larger search was conducted in January 2018, with subsequent searches restricted to focus on acceleration, speed and velocity outcomes made on August 2020 and May 2022.

### *Study Selection:*

A two-stage selection strategy (Title/Abstract and full text screen) was independently undertaken by three members of the review team (AM, AH and RA). The independent screeners convened at the end of each screening stage to resolve any discrepancies. During the full text screen reasons for exclusion were categorised as one or more of the following: 1) ineligible population; 2) ineligible intervention; 3) ineligible outcomes; 4) insufficient data; and (5) other.

### *Data Extraction:*

A codebook and extraction files were developed using Microsoft excel, and pre-piloted prior to data extraction. Data were extracted independently by three members of the review team (AM, AH and RA) into separate extraction files then merged following discussion of any differences. The following data were extracted where available: study details (authors, year, total number of groups, control type); participant characteristics (final study n, sex, training status, age); exercise characteristics (type, intervention duration, frequency, intensity, volume); pre and post-intervention data (means and standard deviations) collected from: 1) sprint performance; 2) maximum strength (tests of lower body strength where time was not limited, e.g. isometric mid-thigh pull); 3) power: any direct measurement of power in Watts measured during lower body activities and measures of jump height; and 4) jump performance measured in distance. Participants for each study were categorised on the basis of their experience with structured S&C as novices (<1 year experience), intermediates (1-5 year experience) and advanced (>5 year experience) (53). Interventions were categorised based on the key exercises matching the definitions outlined in table 1. Intensity for resistance training interventions were coded as low and high based on a percentage 1RM (≤80% low and >80% high). Ballistic resistance training and speed training interventions were always coded as high intensity due to the maximal intent of the movements, unless a submaximal intensity was specifically stated. Where studies did not provide a percentage 1RM, the number of repetitions performed per set was used to estimate intensity based on equivalent percentages suggested by Haff and Triplett (54). Plyometric training intensity was based on the characteristics of the included exercises, for example, extensive pogo jumps, vertical jumps and double leg static jump variations were generally coded as low intensity. Uni-lateral jumps for height or distance, repeated bounding and drop/depth jumps >30 cm drop height were categorised as high intensity. Training volume for resistance training interventions was categorised as low or high based on the average number of repetitions performed in the main exercises (1-9 low and ≥10 high). The same method was applied to ballistic resistance exercise with different cut-offs (1-6 low and >6 high). Training volume for plyometric training was based on the average number of foot contacts performed per session (<120 low and ≥120 high). Categorisation of speed training volume was based on the average number of total sprints performed per session (<10 low and ≥10 high).

## Certainty in cumulative evidence

Certainty in meta-analytic outcomes was assessed by RA and PS using the Grading of Recommendations Assessment Development and Evaluation (GRADE) approach (55). Potential downgrading factors included risk of bias, inconsistency, imprecision, and the presence of small-study effects. Risk of bias for each study was appraised using the PEDro scale based on the Delphi list developed by Verhagen et al., (56). A total of two domains were evaluated including: (1) internal validity; and (2) statistical information. For non-comparator studies, the PEDro scale was modified to only include questions 8, 9 and 11. Individual studies were assigned a final risk of bias score interpreted as 8-10 "low risk" (80% +); 6-7 "moderate risk" (60 – 79%); ≥ 6 "high risk" (≥ 59%) (57). Assessment of risk of bias for meta-analytic outcomes was conducted by calculating the mode risk of bias score from the studies comprising outcomes in the analysis. Inconsistency was assessed based on meta-analysis results and comparison of central and variance parameter estimates and identified as high risk if between study standard error was >90% of effect size. Imprecision was judged based on the number of data points available (number of studies, treatment arms and outcome measures) and width of credible intervals for central estimates. Certainty of evidence was categorised as high/moderate/low/very low. Assessments began with a categorisation of high certainty and were downgraded one level for each of the domains that were not judged low risk.

## Data Synthesis

A Bayesian framework was chosen as it provides a flexible modelling approach that enables results to be interpreted intuitively through reporting of subjective probabilities (58). The effects of each intervention were quantified by calculating effect sizes in the form of standardized mean differences (SMDs). To account for the small sample sizes generally used in S&C, a bias correction was applied. Magnitude-based SMDs obtained by dividing the mean difference by the pre-intervention standard deviation are the most popular form of effect size used in meta-analyses in sport and exercise science and are informative when considering the change an individual can be expected to make relative to a population pre- to post-intervention (59). Effect sizes were calculated for all outcomes that met the inclusion criteria with most studies providing multiple effect sizes. All relevant effect sizes were incorporated within each meta-analysis comprising a nested four-level mixed effects structure which is presented in the supplementary files (SF-2). The series of nestings included the individual study (level 4), the outcome (level 3, e.g. studies generally included multiple outcomes), the measurement occasion (level 2, e.g. studies frequently measured outcomes at multiple points following baseline) and the within-study sampling variance (level 1) which were calculated according to standard distributions with bias correction for small samples applied (59, 60).

To investigate potential differences in effect size distributions across training modes and moderators such as sprint distance, training dose and training status, meta-regressions were performed with variables categorised as factors and entered into meta-analysis models as fixed effects. Meta-regressions were presented by selecting one level of the factor as a reference to make comparisons with the median and 95% CrI given ($\beta_{Reference:Comparison}$ = median [95%CrI: lower bound to upper bound], such that $\beta>0$ indicates an increased effect of the comparison relative to the reference).

Meta-regressions were also performed to investigate potential associations between changes in physical capacity (strength, power, or vertical jump performance) and changes in sprint performance. First, separate meta-analyses were conducted pooling either strength, power, vertical jump, or sprint performance data. For each meta-analysis, individual studies were allocated a single study specific effect size and associated standard error. This effect size represented a 'shrunken estimate' across all data points included from the study, borrowing strength from data across all studies and being pulled towards the pooled mean to represent more probable values. The study specific effect size and standard error were taken from the study posterior distribution as the median and standard deviation, respectively. An illustration of study specific posterior distributions can be seen in the Bayesian forest plot in figure 2, where the black circles represent the median and the width of the distribution reflects the standard error. A final series of weighted meta-regressions were then performed with the shrunken sprint performance estimates for the dependent variable along with their standard error, and the shrunken strength, power, or vertical jump estimates as continuous moderator values with weighting applied based on the reciprocal of their standard error. This approach was used to account for the use of different numbers of independent and dependent outcomes across studies.

Weakly informative Student-t priors with 3 degrees of freedom were used for intercept and slope parameters in regressions, and half Student-t priors with 3 degrees of freedom were used for variance parameters (61). Inferences from all analyses were performed on posterior samples generated using the Hamiltonian Markov Chain Monte Carlo method with four chains for 20,000 iterations with a burn-in period of 10,000. Interpretations were based on the median value ($ES_{0.5}$: 0.5-quantile), the range within credible intervals (CrIs). Bayesian CrIs can be interpreted probabilistically, such that with a 95% CrI there is a 95% probability that the true (unknown) estimate would lie within the interval given the priors implemented and the evidence provided by the observed data. Additionally, the $ES_{0.5}$ represents the centre of the posterior such that values close to this point are generally more probable. Analyses were performed using the R wrapper package brms interfaced with Stan to perform sampling (62). Convergence of parameter estimates was obtained for all models with Gelman-Rubin R-hat values below 1.1 (63).

## Results

The literature search initially identified a total of 119,642 potential studies, after removal of duplicates and title and abstract screening, 804 full articles were evaluated according to the inclusion/exclusion criteria. A total of 157 studies comprising a median group size of 11 (IQR:9-13), met the inclusion criteria and featured sufficient data to be included in the meta-analysis (Figure 1). A full reference list of the included studies is provided in the supplementary files (SF-2). A total of 1805 outcomes were extracted (sprint time: 699; sprint velocity: 131; strength: 319; power: 229; jump: 427), from interventions categorised as resistance (34.0%), sprint (18.0%), plyometric (10.0%) and a combination of the three (38.0%). Most outcomes were obtained from participants categorised as intermediates (30.4%), followed by novices (57.5%) and advanced (12.1%) based on their S&C experience. A high percentage of outcomes were obtained from male only groups (82.7%), followed by female only (10.4%), then mixed (6.9%) groups. Measurement of outcomes was performed on a consistent basis with a tight distribution (median: 8; IQR:6-9 weeks). Strength of evidence assessments for the meta-analysis outcomes and risk of bias for individual studies are presented in supplementary files (SF-4 & SF-5).

*Meta-analysis: Sprint outcomes*

Meta-analysis of all sprint outcomes estimated a mean pooled effect size of $\text{SMD}_{\text{Pre}_{0.5}}$ = 0.44 [95%CrI: 0.37 to 0.52; very low certainty], with between study standard deviation $\sigma_{v_{0.5}}$ = 0.46 [75%CrI: 0.42 to 0.50] which accounted for approximately 70% of the variance across levels (Figure 2). Analyses indicated that the mean pooled effect size for sprint outcomes measured by time or velocity were equivalent ($\beta_{\text{Time:Velocity}_{0.5}}$ = 0.02 [95%CrI: -0.09 to 0.14; very low certainty]). In addition, estimated pooled means were similar across sprint distances ($\beta_{\leq 10\text{m}:\leq 20\text{m}_{0.5}}$ = -0.03 [95%CrI: -0.09 to 0.05; low certainty], $\beta_{\leq 10\text{m}:\leq 30\text{m}_{0.5}}$ = -0.04 [95%CrI: -0.14 to 0.07; low certainty], $\beta_{\leq 10\text{m}:\leq 40\text{m}_{0.5}}$ = -0.01 [95%CrI: -0.10 to 0.09; very low certainty]). The largest estimated mean pooled effect size was obtained for interventions comprising resistance training ($\text{SMD}_{\text{Pre}_{0.5}}$ = 0.55 [95%CrI: 0.36 to 0.78; very low certainty]); however, there was considerable overlap in estimates across all intervention types ($\beta_{\text{Sprint:Resistance}_{0.5}}$ = 0.11

[95%CrI: -0.03 to 0.26; low certainty], $\beta_{\mathrm{Sprint:Plyometric}_{0.5}}$ = -0.03 [95%CrI: -0.21 to 0.16; low certainty], $\beta_{\mathrm{Sprint:Combined}_{0.5}}$ = 0.07 [95%CrI: -0.08 to 0.20; low certainty]).

Figure 1. PRISMA flow diagram depicting the search and screening process.

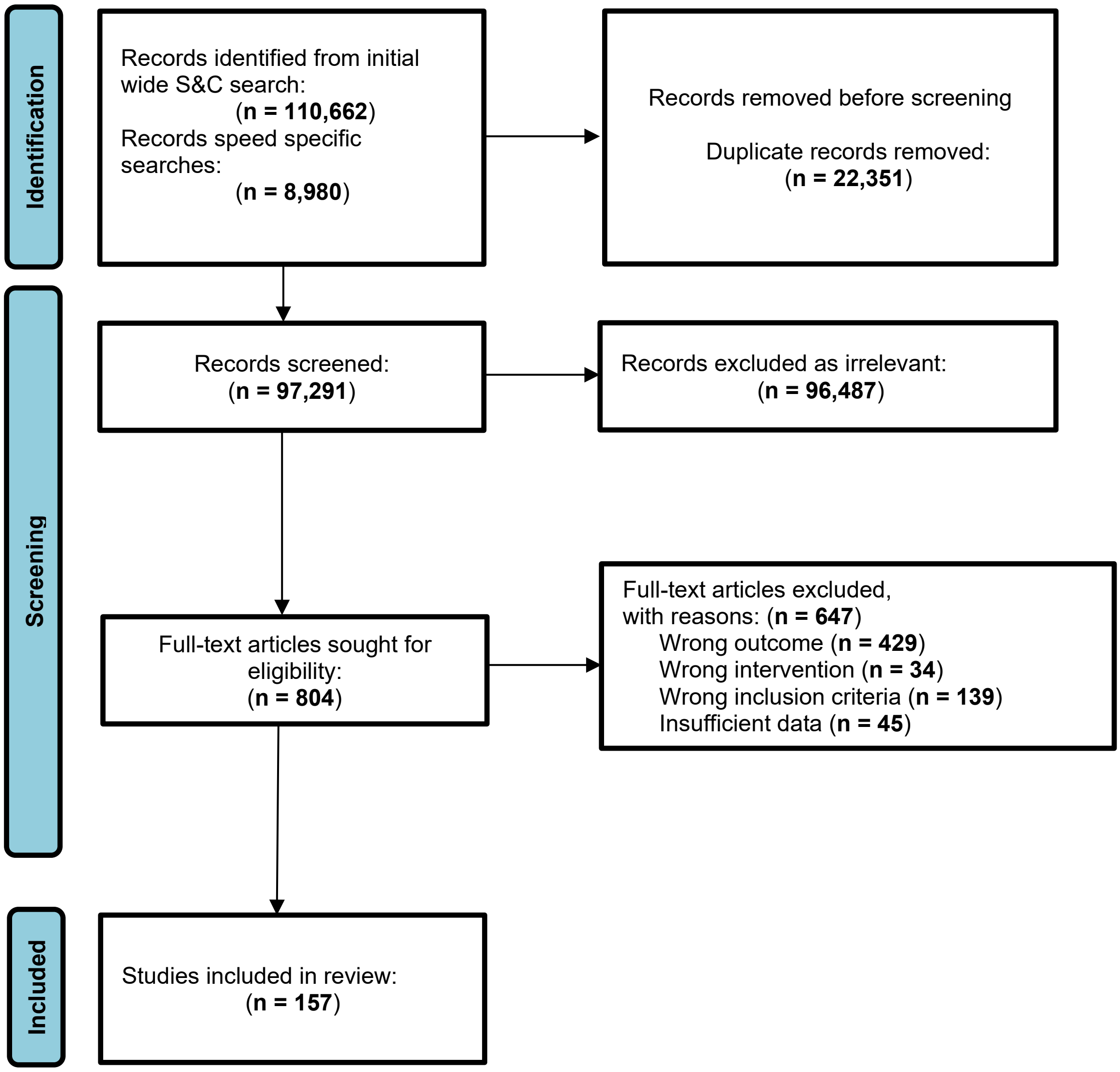
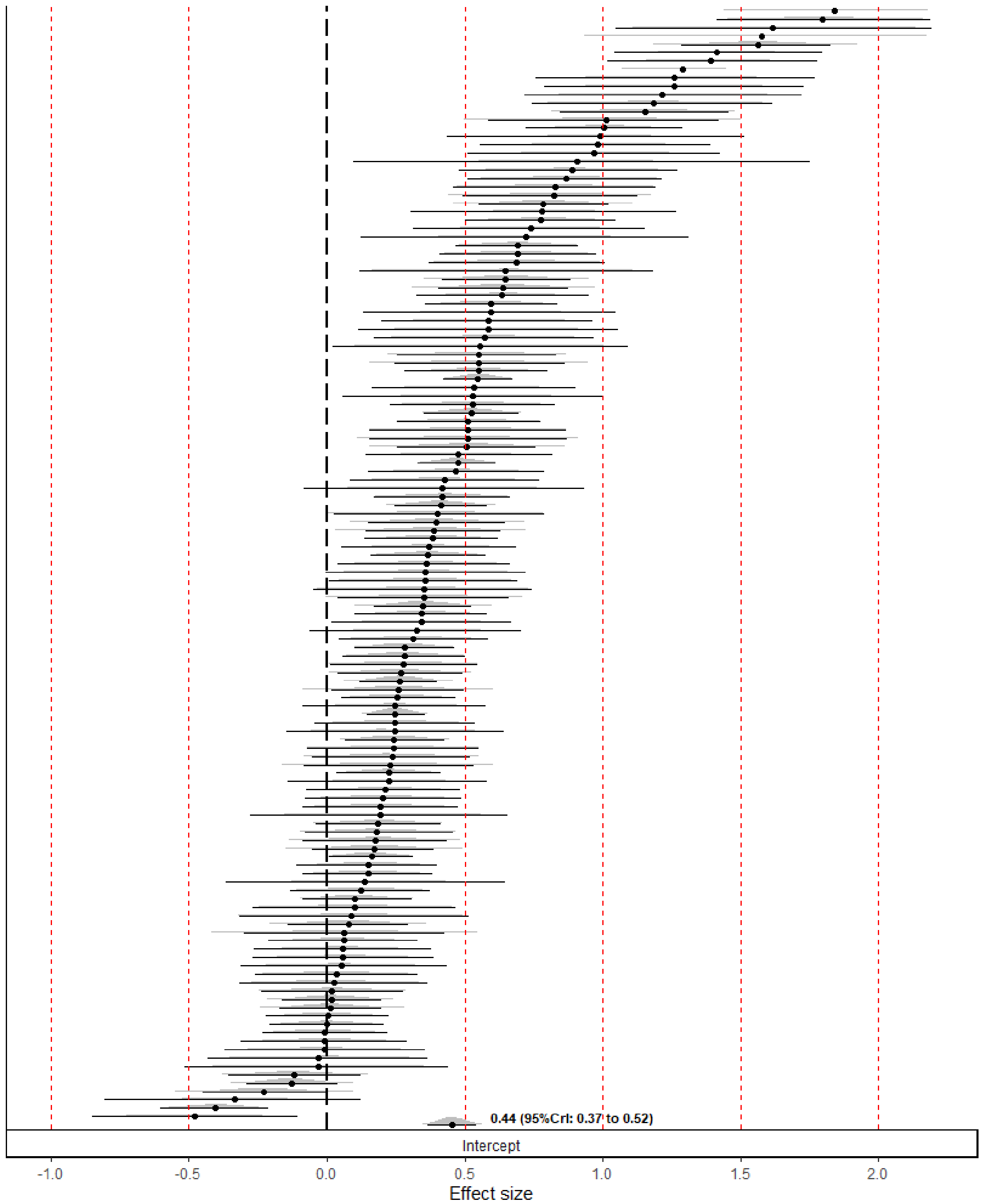


Figure 2. Bayesian forest plot estimating pooled mean across all sprint outcomes



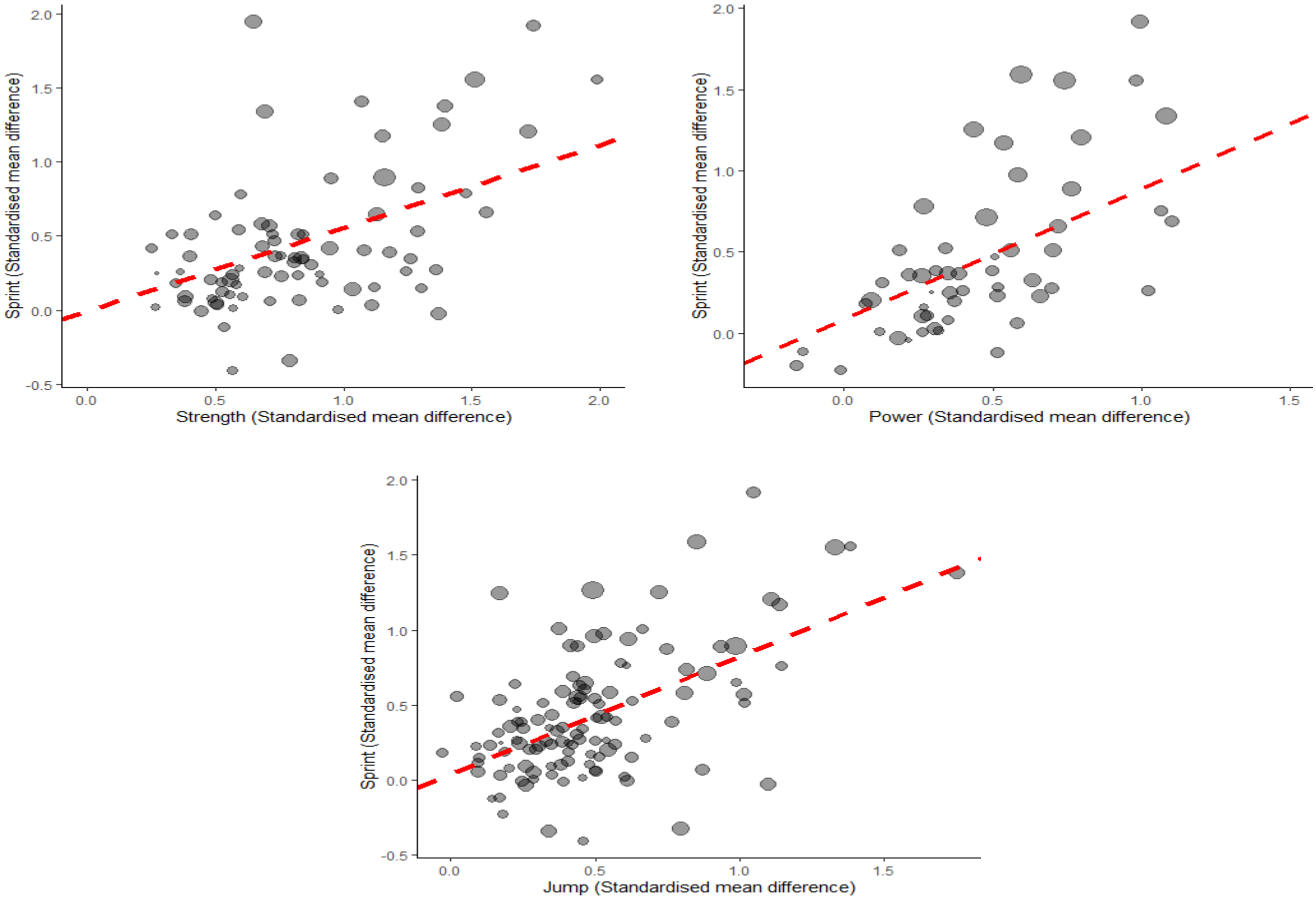

**Distributions represent "shrunken estimates" from individual studies based on all relevant effect sizes, the random effects model fitted, and borrowing of information across studies to reduce uncertainty. Black circles and connected intervals represent the median value and 95% credible intervals for the shrunken estimates. Black dashed line denotes the zero line, with red lines set at 0.5 intervals. CrI: Credible interval.**

Further moderator analyses identified increased mean pooled effect size with interventions comprising high intensity compared with lower intensity activity ($\beta_{\text{Low:High}_{0.5}}$ = 0.17 [95%CrI: 0.01 to 0.33; very low certainty]). In contrast, considerable overlap and limited evidence of moderating effects were obtained for training volume ($\beta_{\text{Low:High}_{0.5}}$ = -0.02 [95%CrI: -0.14 to 0.10; low certainty]), intervention length ($\beta_{\text{<8Weeks:≥8Weeks}_{0.5}}$ = 0.12 [95%CrI: 0.01 to 0.23; low certainty]), and participant S&C training status ($\beta_{\text{Novice:≥Intermediate}_{0.5}}$ = -0.06 [95%CrI: -0.18 to 0.07; low certainty], $\beta_{\text{Novice:≥Advanced}_{0.5}}$ = 0.01 [95%CrI: -0.24 to 0.26; low certainty]). In a sub-analysis conducted on all sprint outcomes obtained from interventions categorised as free sprint or resisted sprint, an increased pooled mean effect size was estimated for resisted sprint interventions ($\beta_{\text{Free:Resisted}_{0.5}}$ = 0.19 [95%CrI: 0.09 to 0.29; moderate certainty]).

*Meta-analysis: Relationships between sprint and other outcomes*

From the 157 studies included in the review, 82 (52%) studies included 318 strength outcomes, 56 (36%) studies included 229 power outcomes, and 118 (75%) studies included 424 jump outcomes. Mean pooled effect sizes of $\text{SMD}_{\text{Pre}_{0.5}}$ = 0.70 [95%CrI: 0.60 to 0.79; low certainty], $\text{SMD}_{\text{Pre}_{0.5}}$ = 0.43 [95%CrI: 0.31 to 0.54; moderate certainty], and $\text{SMD}_{\text{Pre}_{0.5}}$ = 0.49 [95%CrI: 0.42 to 0.57; low certainty], were obtained for strength, power and jump outcomes, respectively. To quantify relationships between magnitudes of improvement in sprint outcomes and all other outcomes, shrunken estimates from each intervention group were obtained combining all outcomes from each category into a single estimate. Relatively strong relationships were obtained between improvements in sprint and all other outcome measures ($\beta_{\text{Strength}_{0.5}}$ =0.56 [95%CrI: 0.36 to 0.77; low certainty], $\beta_{\text{Power}_{0.5}}$ =0.80 [95%CrI: 0.50 to 1.0; low certainty], $\beta_{\text{Jump}_{0.5}}$ =0.78 [95%CrI: 0.57 to 0.97; low certainty]). Bubbleplots illustrating the relationship between shrunken estimates across studies are presented in Figure 3.

Figure 3. Bubble plot illustrating the relationships between improvements in physical variables (Left: Strength; Right: Power; Bottom: Jump) and sprint performance across intervention studies.




**Slopes of regression lines:** $\boldsymbol{\beta_{\text{Strength}_{0.5}}}$ **=0.56 [95%CrI: 0.36 to 0.77];** $\boldsymbol{\beta_{\text{Power}_{0.5}}}$ **=0.80 [95%CrI: 0.50 to 1.0];** $\boldsymbol{\beta_{\text{Jump}_{0.5}}}$ **=0.78 [95%CrI: 0.57 to 0.97].**

## Discussion

The present study represents one of the largest meta-analyses to date investigating the transfer of S&C training to sprint performance in team sport athletes. Meta-analyses conducted across all training modes identified similar improvements in sprint performance across distances of 5 to 40 m, for both time and velocity. Considerable overlap in pooled estimates were obtained for resistance, sprint, plyometric and combined training modes, with the highest point estimate obtained for resistance training. The strongest moderating effects were identified for training intensity and intervention duration. Higher intensity training, including the addition of resistance during sprint training, resulted in increases in standardised mean differences of approximately 0.15 to 0.20. Greater improvements were also associated with longer duration interventions. In contrast, limited evidence of moderating effects was obtained for training volume, or S&C training experience. Across the included studies, similar standardised mean difference improvements were obtained for strength, power and jump performance, with pooled mean values ranging between 0.50 and 0.70. In addition, similar strong relationships were identified across studies for improvement in strength, power or jump performance, and improvement in sprint performance. Weighted regressions estimated that for each standard deviation improvement in the physical variables, sprint performance would be expected to improve by 0.5 to 0.8 standard deviations.

The studies included in the present systematic review and meta-analysis comprised primarily team sport athletes that were novices in S&C (59% of studies) with less than 1 year training experience. In addition, training interventions were generally short, with the median duration for data collection equal to 8 weeks (IQR:6-9 weeks). No evidence of a moderating effect was identified for experience in S&C. The focus on relatively untrained populations has been viewed as a consistent limitation within S&C research as it is expected that untrained individuals will elicit greater training effects due to neural and motor skill adaptations, rather than the potential targeted morphological adaptations (3). However, the results from the current review did not provide clear evidence of differences in sprint performance improvements across novice, intermediate and advanced team sport athletes, categorised based on their S&C training experience. These results are consistent with the findings of a recent meta-analysis (45) conducted with team sport athletes performing either complex or contrast training. Cormier et al. (45) categorised athlete status based on their level of competition as amateurs or professionals, and reported substantial overlap in effect size estimates for the groups of sprint times across distances from 10 to 40 m. In contrast, in another meta-analysis conducted with healthy adults, Seitz et al. (37) reported differences across groups based on the level of practice, with some sub-analyses indicating greater improvement in sprinting performance with increasing level of practice. Differences across reviews may be due to several factors including categorisation based on either the level of the athlete according to their ability in the sport, or their experience with regards to S&C. The approach adopted in the present review could be considered more relevant when assessing the transfer of training with regards to physical improvements within the context of strength and power (2, 3, 52, 64-66).

In a recent very large meta-analysis (3), the effects of specificity were clearly identified with coupling between training intervention and outcome shown to result in an approximate 0.2 increase in standardised mean difference compared to non-coupled interventions and outcomes. In the current review, considerable overlap in improved sprint performance was obtained for resistance, plyometric, sprint, and combined intervention types. However, some evidence was obtained indicating that the greatest improvements in sprint performance occurred with resistance-based interventions. It is important to note that these results do not contradict the specificity findings of the previous large scale meta-analysis. That is, resistance training was shown previously to result in the largest increases across all outcome measures (strength, agility, jump, sprint, and explosiveness), but that additional increases were obtained when resistance training was combined with strength outcomes (3). In contrast, sprint training was shown to result in the lowest increases across all outcomes measures, but that an additional specificity effect occurred so that sprint outcomes were improved to a greater degree. The results from the current meta-analysis identify that these relative general and specific effects appear to balance each other out to some degree, such that each of the training methods results in similar improvements in sprint performance, with potentially resistance training providing the largest improvements in team sport athletes. The findings are in agreement with a recent meta-analysis conducted with football code athletes that showed similar improvements in sprint performance for training methods categorised as primary (sprint technique drills and unresisted sprinting), secondary (forms of resisted sprint training), tertiary (non-specific sprint training including strength and/or plyometric training), combined specific (combinations of primary unresisted and secondary resisted sprint training) combined (combinations of the tertiary, non-specific training and primary or secondary sprint specific training) (46, 47).

The results of the current review also highlighted that across all training types increased intensity resulted in greater improvements in sprint performance. This finding agrees with previous research demonstrating an ordered effect for resistance training interventions and improvements in sprint performance across intensities categorised as light (0.8% improvement), medium (3.3% improvement) and high (5.0% improvement) (37). In the present review the increased effectiveness of higher intensity exercise on improved sprint performance was also demonstrated when comparing free sprint and resisted sprint interventions. Whilst free sprint training is most specific to the target task of improving sprint performance, the ability to overload and develop physical output during the target task becomes compromised. In contrast, resisted sprint training allows for the ability to overload kinetic outputs such as the production of force and power in opportune directions, whilst also maintaining high levels of kinematic similarity. In a systematic review of the use of resisted sled training, Petrakos et al (41) identified that non-specifically sprint trained athletes demonstrate greater rates of improvement from interventions that target sprint-specific muscle output or technical efficiency, in which the use of resisted sprint training could encompass both. Research and use of resisted sprint training has gained popularity over recent years (66). However, considerations are required in load selection to balance overload while maintaining levels of specificity. Meta-analysis results from Alcaraz et al. (43) concluded resisted sprint training (sled towing) was most beneficial with loads <20% body mass at up to 20 m distances. More recently, very heavy resisted sled training (80+% body mass) has also been shown to improve horizontal force, power, and mechanical efficiency in soccer players with the greatest improvements measured during accelerative sprinting (<20m), with small or unclear improvements in maximum velocity (67). In the current review no evidence of differential improvements in sprint performance were identified across distances of between 5 and 40 m. However, the possibility that differential effects exist within specific training methods is possible.

To the authors' knowledge, the current review is the first to implement an extensive analysis approach across many studies to quantify the magnitude of transference from improvements in strength, power and jump height to improvements in sprint performance of team sport athletes. The results showed similar strong associations between all three physical factors and sprint performance with the point estimates of the beta-coefficient ranging from 0.56 to 0.80. Additionally, visual inspection of the data indicated that a linear relationship may be appropriate (Figure 3). The results obtained in the current review support those by Seitz et al. (37) who reported an absolute correlation value of 0.77 between improvements in the squatting and sprint performance. In the analysis by Seitz et al. (37), precision in effect size estimates were not accounted for when calculating the association. Additionally, Seitz et al. (37) included multiple outcomes from the same study without accounting for dependencies in the data. Collectively, not accounting for dependencies and different levels of precision in the data is likely to overestimate confidence in the estimate provided by Seitz et al. (37). In the present review a Bayesian approach was adopted using shrunken estimates that borrow information across studies tending to increase precision in study estimates. Additionally, the present study used a single effect size value from each study informed by the measurement of multiple outcomes and performed a weighted regression accounting for uncertainty in the individual study estimates. The process resulted in similar point estimate to Seitz et al (37), but uncertainty in the estimate in the current study was wider. The findings of the current review demonstrate that similar strong relationships were obtained for improvements in power and jump performance with improved sprint performance, further highlight that implementation of the most effective S&C methods to develop the physical capabilities of team sport athletes should be expected to result in substantive improvements in sprint performance.

Whilst the current review represents the largest systematic review employing robust meta-analytic approaches to investigate the effect of S&C interventions on sprint performance within team sports, there are multiple research, process and statistical limitations that should be considered. Although an extensive literature search was implemented the process was not exhaustive and many studies particularly those published in languages other than English are not included. The certainty of the evidence presented in this review was generally low based on evaluations using the GRADE approach. This was due to the consistent high risk of bias, high risk of inconsistency due to the heterogenous nature of the research with regards to many intervention and participant related factors, and frequent risk of small-study effects that have been shown to results in very large and potentially unrealistic effect size estimates (68). Previous meta-analyses have categorised playing level (amateur, sub-elite, elite) as a moderating variable and/or indicator of experience whereas, the current analysis included training status based on stated years of S&C experience. However, several studies did not specify participant training history, meaning this field was estimated based on playing level and values of outcome variables. Additionally, future research in the area should consider applications of combined specific training methods such as combinations of free and resisted sprint training versus non-specific training methods (resistance and plyometric training), and to the type and intensity of load applied during resisted sprint training.

The statistical limitations of the review include those common to many meta-analyses and some specific to the approaches adopted. The use of meta-regressions is generally recommended to explore associations between a limited number of between study factors and effects sizes (70). Most meta-analyses including that presented here, however, are conducted on aggregate data from studies comprising different combinations of potentially relevant factors including training and participant characteristics. Firstly, estimates from individual meta-regressions may be confounded by imbalances in other factors. Secondly, it is expected that there will be differences between associations of effects with aggregate study-level data and true associations obtained from individuals which has been referred to as the ecological fallacy or aggregation bias (71). Thirdly, even where associations from aggregate level data appropriately reflect those at the individual level, there may be limited causal structures such that targeting development in one factor (e.g. strength) may not improve the other (e.g. speed) by the expected magnitude.

Statistical limitations specific to this review include the layering of regressions and their shrunken estimates to quantify relationships between changes in sprint performance and strength, power and jumping. It is possible that this process may have caused additional dependencies within the data thereby influencing estimates. However, sample sizes were generally consistent across the studies such that the estimates were shrunken primarily based on the magnitude of the effects calculated.

## Practical applications

The findings from the current systematic review and meta-analysis demonstrate that both non-direct and direct S&C training can provide sufficient stimulus when attempting to improve sprint performance in team sport athletes. Evidence was obtained indicating that resistance training may produce the largest improvements, but considerable overlap with other methods should be expected. In addition, more successful S&C interventions with regards to development of strength, power, or explosive performance in the form of vertical jumping, are expected to result in the largest improvements in sprinting performance. Therefore, practitioners should aim to maximise improvements in such physiological qualities to increase the possible transference to sprinting performance. Collectively, the findings suggest that when attempting to develop sprinting performance in team sport athletes, practitioners should aim to implement periodized training interventions incorporating the most effective S&C interventions to develop strength, power, and explosive ability. Additionally, interventions that feature high intensity loading for each training mode are likely to be the most effective, including resisted sprint training. Based on these results, practitioners and athletes' can use short time periods (~8 to 12 weeks), potentially during off-season or pre-season, to incorporate high intensity loading, through non-direct (resistance training, plyometric or combined) or direct (free sprint or resisted sprint) training methods to overload and promote physiological adaptions likely to lead to improvements in sprint performance. Further research is required to investigate which periodized approaches are most effective, however, the finding that many training types improve sprint performance and the existence of strong positive relationships between magnitude of improvements between physical factors and sprint performance suggests that many contemporary S&C approaches are likely to be effective.

DECLARATIONS:

Ethics Approval and Consent to Participate:

Not applicable.

Consent for Publication:

Not applicable

Availability of Data and Materials:

Sections of the large data set can be made available from the corresponding author on reasonable request.

Competing Interests:

The authors declare that they have no competing interests.

Funding:

Not applicable

Authors' Contributions:

AM, PS and KB designed the protocol. AM, AH and RA conducted the searches and screened the studies. PS developed and piloted the codebook with ongoing critical input from AM and KB. AM, AH and RA extracted the data. AH and RA conducted the quality appraisal of all articles. PS undertook the statistical analysis with critical input from AM. AM and PS wrote the first draft of the manuscript with ongoing critical input from all authors.

Acknowledgements:

Not applicable

Authors' Information:

Not applicable.

References


1. Kraemer WJ, Ratamess NA, Flanagan SD, Shurley JP, Todd JS, Todd TC. Understanding the science of resistance training: an evolutionary perspective. *Sports Med* 47:2415-35, 2017.
2. Suchomel TJ, Nimphius S, Stone MH. The importance of muscular strength in athletic performance. *Sports Med* 46:1419-49, 2016.
3. Swinton PA, Burgess K, Hall A, Greig L, Psyllas J, Aspe R, Maughan P, Murphy A. A Bayesian approach to interpret intervention effectiveness in strength and conditioning: Part 1. A meta-analysis to derive context-specific thresholds. *Pre-print available from SportRxiv*. https://doi.org10.51224/SRXIV.9
4. Brearley S, Bishop C. Transfer of training: How specific should we be?. *Strength Cond J* 41:97-109, 2019.
5. Issurin VB. Training transfer: scientific background and insights for practical application. *Sports Med* 43:675-94, 2013.
6. Suarez DG, Wagle JP, Cunanan AJ, Sausaman RW, Stone MH. Dynamic correspondence of resistance training to sport: a brief review. *Strength Cond J* 41:80-8, 2019.
7. Kraemer WJ, Ratamess NA. Fundamentals of resistance training: progression and exercise prescription. *Med Sci Sports Exerc* 36:674-88, 2004.
8. Bosch F, Cook K. *Strength training and coordination: an integrative approach*. Rotterdam: 2010 Publishers; 2015.
9. Wilson GJ, Lyttle AD, Ostrowski KJ, Murphy AJ. Assessing dynamic performance: A comparison of rate of force development tests. *J Strength Cond Res* 9:176-81, 1995.
10. Cronin JB, Hansen KT. Strength and power predictors of sports speed. *J Strength Cond Res* 19:349-57, 2005.
11. Peterson MD, Alvar BA, Rhea MR. The contribution of maximal force production to explosive movement among young collegiate athletes. *J Strength Cond Res* 20:867-73, 2006.
12. West DJ, Owen NJ, Jones MR, Bracken RM, Cook CJ, Cunningham DJ, Shearer DA, Finn CV, Newton RU, Crewther BT, Kilduff LP. Relationships between force-time characteristics of the isometric midthigh pull and dynamic performance in professional rugby league players. *J Strength Cond Res* 25:3070-5, 2011.
13. Duthie G, Pyne D, & Hooper S. Applied Physiology and Game Analysis of Rugby Union. *Sports Med* 33: 973–991, 2003.
14. Little T, Williams AG. Specificity of acceleration, maximum speed, and agility in professional soccer players. *J Strength Cond Res* 19:76–8, 2005.
15. Gabbett T, Jenkins DG, Abernethy B. Relative importance of physiological, anthropometric, and skill qualities to team selection in professional rugby league. *J Sports Sci* 29: 1453-1461, 2011.
16. Kawamori N, Nosaka K, Newton RU. Relationships between ground reaction impulse and sprint acceleration performance in team sport athletes. *J Strength Cond Res* 27:568-73, 2013.
17. Kirkpatrick J, Comfort P. Strength, Power, and Speed Qualities in English Junior Elite Rugby League Players. *J Strength Cond Res* 27: 2414-2419, 2013.
18. LaPlaca DA, McCullick BA. National Football League Scouting Combine Tests Correlated to National Football League Player Performance. *J Strength Cond Res* 34:1317-1329, 2020.
19. Baker D, Nance S. The Relation Between Running Speed and Measures of Strength and Power in Professional Rugby League Players. *J Strength Cond Res* 13:230-235, 1999.

20. Wisløff U, Castagna C, Helgerud J, Jones R, Hoff J. Strong correlation of maximal squat strength with sprint performance and vertical jump height in elite soccer players. *Br J Sports Med* 38:285-8, 2004.
21. McBride JM, Blow D, Kirby TJ, Haines TL, Dayne AM, Triplett NT. Relationship between maximal squat strength and five, ten, and forty yard sprint times. *J Strength Cond Res* 23:1633-6, 2009.
22. Swinton PA, Lloyd R, Keogh JW, Agouris I, Stewart AD. Regression models of sprint, vertical jump, and change of direction performance. *J Strength Cond Res* 28:1839-48, 2014.
23. Cunningham DJ, West DJ, Owen NJ, Shearer DA, Finn CV, Bracken RM, Crewther BT, Scott P, Cook CJ, Kilduff LP. Strength and power predictors of sprinting performance in professional rugby players. *J Sports Med Phys Fitness* 53:105-11, 2013.
24. Furlong LA, Harrison AJ, Jensen RL. Measures of strength and jump performance can predict 30-m sprint time in rugby union players. *J Strength Conditioning Res* 35:2579-83, 2021.
25. Stølen T, Chamari K, Castagna C, Wisløff U. Physiology of soccer: an update. *Sports Med* 35:501-36, 2005.
26. Brazier J, Antrobus M, Stebbings GK, Day SH, Callus P, Erskine RM, Bennett MA, Kilduff LP, Williams AG. Anthropometric and Physiological Characteristics of Elite Male Rugby Athletes. *J Strength Cond Res* 34:1790-1801, 2020.
27. Gabbett T, Kelly J, Ralph S, Driscoll D. Physiological and anthropometric characteristics of junior elite and sub-elite rugby league players, with special reference to starters and non-starters. *J Sci Med Sport* 12:215-22, 2009.
28. Chiwaridzo, M., Ferguson, G.D. & Smits-Engelsman, B.C.M. Qualities or skills discriminating under 19 rugby players by playing standards: a comparative analysis of elite, sub-elite and non-rugby players using the SCRuM test battery. *BMC Res Notes* 12:1-8, 2019.
29. Gissis I, Papadopoulos C, Kalapotharakos VI, Sotiropoulos A, Komsis G, Manolopoulos E. Strength and speed characteristics of elite, subelite, and recreational young soccer players. *Res Sports Med* 14:205-14, 2006.
30. Sierer SP, Battaglini CL, Mihalik JP, Shields EW, Tomasini NT. The National Football League Combine: performance differences between drafted and nondrafted players entering the 2004 and 2005 drafts. *J Strength Cond Res* 22:6-12, 2008.
31. Cometti G, Maffiuletti NA, Pousson M, Chatard JC, Maffulli N. Isokinetic strength and anaerobic power of elite, subelite and amateur French soccer players. *Int J Sports Med* 22:45-51, 2001.
32. le Gall F, Carling C, Williams M, Reilly T. Anthropometric and fitness characteristics of international, professional and amateur male graduate soccer players from an elite youth academy. *J Sci Med Sport* 13:90-5, 2010.
33. Stein JG, Gabbett TJ, Townshend AD, Dawson BT. Physical qualities and activity profiles of sub-elite and recreational Australian football players. *J Sci Med Sport* 18:742-7, 2015.
34. Aquino R, Alves IS, Padilha MB, Casanova F, Puggina EF, Maia J. Multivariate Profiles of Selected versus Non-Selected Elite Youth Brazilian Soccer Players. *J Hum Kinet* 60:113-121, 2017.
35. Trecroci A, Longo S, Perri E, Iaia FM, Alberti G. Field-based physical performance of elite and sub-elite middle-adolescent soccer players. *Res Sports Med* 27:60-71, 2019.
36. Sáez de Villarreal E, Requena B, Cronin JB. The effects of plyometric training on sprint performance: a meta-analysis. *J Strength Cond Res* 26:575-84, 2012.

37. Seitz LB, Reyes A, Tran TT, Saez de Villarreal E, Haff GG. Increases in lower-body strength transfer positively to sprint performance: a systematic review with meta-analysis. *Sports Med* 44:1693-702, 2014.
38. Haugen T, Seiler S, Sandbakk Ø, Tønnessen E. The Training and Development of Elite Sprint Performance: an Integration of Scientific and Best Practice Literature. *Sports Med Open* 5:44, 2019.
39. Rumpf MC, Lockie RG, Cronin JB, Jalilvand F. Effect of Different Sprint Training Methods on Sprint Performance Over Various Distances: A Brief Review. *J Strength Cond Res* 30:1767-85, 2016.
40. Bolger R, Lyons M, Harrison AJ, Kenny IC. Sprinting performance and resistance-based training interventions: a systematic review. *J Strength Cond Res* 29:1146-56, 2015.
41. Petrakos G, Morin JB, Egan B. Resisted Sled Sprint Training to Improve Sprint Performance: A Systematic Review. *Sports Med* 46:381-400, 2016.
42. Feser EH, Macadam P, Cronin JB. The effects of lower limb wearable resistance on sprint running performance: A systematic review. *Eur J Sport Sci* 20:394-406, 2020.
43. Alcaraz PE, Carlos-Vivas J, Oponjuru BO, Martínez-Rodríguez A. The Effectiveness of Resisted Sled Training (RST) for Sprint Performance: A Systematic Review and Meta-analysis. *Sports Med* 48:2143-2165, 2018.
44. Bauer P, Uebellacker F, Mitter B, Aigner AJ, Hasenoehrl T, Ristl R, Tschan H, Seitz LB. Combining higher-load and lower-load resistance training exercises: A systematic review and meta-analysis of findings from complex training studies. *J Sci Med Sport* 22:838-851, 2019.
45. Cormier P, Freitas TT, Rubio-Arias JÁ, Alcaraz PE. Complex and Contrast Training: Does Strength and Power Training Sequence Affect Performance-Based Adaptations in Team Sports? A Systematic Review and Meta-analysis. *J Strength Cond Res* 34:1461-1479, 2020.
46. Nicholson B, Dinsdale A, Jones B, Till K. The Training of Short Distance Sprint Performance in Football Code Athletes: A Systematic Review and Meta-Analysis. *Sports Med* 51:1179-1207, 2021.
47. Nicholson B, Dinsdale A, Jones B, Till K. The Training of Medium-to Long-Distance Sprint Performance in Football Code Athletes: A Systematic Review and Meta-analysis. *Sports Med* 52:257-86, 2022.
48. Moher D, Shamseer L, Clarke M, Ghersi D, Liberati A, Petticrew M, Shekelle P, Stewart LA. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Syst Rev* 4:1-9, 2015.
49. Lesinski M, Prieske O, Granacher U. Effects and dose–response relationships of resistance training on physical performance in youth athletes: a systematic review and meta-analysis.*Br J Sports Med* 50:781-95, 2016.
50. McQuilliam SJ, Clark DR, Erskine RM, Brownlee TE. Free-Weight Resistance Training in Youth Athletes: A Narrative Review. *Sports Med* 50:1567-1580, 2020.
51. Bird SP, Tarpenning KM, Marino FE. Designing resistance training programmes to enhance muscular fitness: a review of the acute programme variables. *Sports Med* 35:841-51, 2005.
52. Plisk SS, Stone MH. Periodisation Strategies. *Strength Cond J* 25:19-37, 2003.
53. Rhea MR. Determining the magnitude of treatment effects in strength training research through the use of the effect size. *J Strength Cond Res* 18:918-20, 2004.

54. Haff GG, Triplett NT eds. *Essentials of strength training and conditioning 4th edition.* Human kinetics, 2015.
55. Guyatt GH, Oxman AD, Vist GE, Kunz R, Falck-Ytter Y, Alonso-Coello P, et al. GRADE: An emerging consensus on rating quality of evidence and strength of recommendations. *BMJ* 336:924-6, 2008.
56. Verhagen AP, De Vet HC, De Bie RA, Kessels AG, Boers M, Bouter LM, Knipschild PG. The Delphi list: a criteria list for quality assessment of randomized clinical trials for conducting systematic reviews developed by Delphi consensus. *J Clin. Epidemiol* 51:1235-41, 1998.
57. Challoumas D, Millar NL. Risk of bias in systematic reviews of tendinopathy management: Are we comparing apples with oranges?. *Transl Sports Med* 4:21-37, 2021.
58. Kruschke JK, Liddell TM. The Bayesian New Statistics: Hypothesis testing, estimation, meta-analysis, and power analysis from a Bayesian perspective. *Psychon Bull Rev* 25:178-206, 2018.
59. Caldwell A, Vigotsky AD. A case against default effect sizes in sport and exercise science. *PeerJ* 8:e10314, 2020.
60. Estrada E, Ferrer E, Pardo A. Statistics for evaluating pre-post change: Relation between change in the distribution center and change in the individual scores. *Front Psychol* 9:2696, 2019.
61. Gelman A. Prior distributions for variance parameters in hierarchical models. *Bayesian Anal* 1:515-34, 2006.
62. Bürkner PC. brms: An R package for Bayesian multilevel models using Stan. *J Stat Softw* 80:1-28, 2017.
63. Gelman A, Carlin JB, Stern HS, Rubin DB. *Bayesian Data Analysis*: Boca Raton, FL:Taylor & Francis; 2014.
64. Rhea MR, Alvar BA, Burkett LN, Ball SD. A meta-analysis to determine the dose response for strength development. *Med Sci Sports Exerc* 35:456-64, 2003.
65. Peterson MD, Rhea MR, Alvar BA. Applications of the dose-response for muscular strength development: Are view of meta-analytic efficacy and reliability for designing training prescription. *J Strength Cond Res* 19:950-8, 2005.
66. Turner AN, Comfort P, McMahon J, Bishop C, Chavda S, Read P, Mundy P, Lake J. Developing powerful athletes Part 2: Practical applications. *Strength Cond J* 43:23-31, 2021.
67. Lockie RG, Murphy AJ, Spinks CD. Effects of resisted sled towing on sprint kinematics in field-sport athletes. *J Strength Cond Res* 17:760-7, 2003.
68. Morin JB, Petrakos G, Jiménez-Reyes P, Brown SR, Samozino P, Cross MR. Very-heavy sled training for improving horizontal-force output in soccer players. *Int J Sports Physiol Perform* 12:840-4, 2017.
69. Swinton P, Burgess K, Hall A, Greig L, Psyllas J, Aspe R, Maughan P, Murphy A. A Bayesian Approach to Interpret Intervention Effectiveness in Strength and Conditioning Part 2: Effect Size Selection and Application of Bayesian Updating. https://doi.org/10.51224/SRXIV.11
70. Geissbühler M, Hincapié CA, Aghlmandi S, Zwahlen M, Jüni P, da Costa BR. Most published meta-regression analyses based on aggregate data suffer from methodological pitfalls: A meta-epidemiological study. *BMC Med Res Methodol* 21:123, 2021.

71. Thompson SG, Higgins JPT. How should meta-regression analyses be undertaken and interpreted?. *Stat Med* 21:1559-1573, 2002.

Figure legends

Figure 1. PRISMA flow diagram depicting the search and screening process.

Figure 2 (TOP): Bayesian forest plot estimating pooled mean across all sprint outcomes

Figure 2 (Bottom): Distributions represent "shrunken estimates" from individual studies based on all relevant effect sizes, the random effects model fitted, and borrowing of information across studies to reduce uncertainty. Black circles and connected intervals represent the median value and 95% credible intervals for the shrunken estimates. Black dashed line denotes the zero line, with red lines set at 0.5 intervals. CrI: Credible interval.

Figure 3 (TOP): Bubble plot illustrating the relationships between improvements in physical variables (Left: Strength; Right: Power; Bottom: Jump) and sprint performance across intervention studies.

Figure 3 (Bottom): Slopes of regression lines: $\beta_{\text{Strength}_{0.5}}$ =0.56 [95%CrI: 0.36 to 0.77]; $\beta_{\text{Power}_{0.5}}$ =0.80 [95%CrI: 0.50 to 1.0]; $\beta_{\text{Jump}_{0.5}}$ =0.78 [95%CrI: 0.57 to 0.97].

**Supplementary File 1:** Checklist of Preferred Reporting items for Systematic Review and Meta-Analysis Protocols (PRISMA-P)

| Section and Topic | Item # | Checklist item | Location where item is reported |
|---|---|---|---|
| **TITLE** | | | |
| Title | 1 | Identify the report as a systematic review. | Title - Page 0 |
| **ABSTRACT** | | | |
| Abstract | 2 | See the PRISMA 2020 for Abstracts checklist. | Abstract - Page 1 |
| **INTRODUCTION** | | | |
| Rationale | 3 | Describe the rationale for the review in the context of existing knowledge. | Introduction - Page 2-5 |
| Objectives | 4 | Provide an explicit statement of the objective(s) or question(s) the review addresses. | Introduction - Page 5 |
| **METHODS** | | | |
| Eligibility criteria | 5 | Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses. | Eligibility Criteria – Page 6-8 |
| Information sources | 6 | Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted. | Search Strategy – Page 8 |
| Search strategy | 7 | Present the full search strategies for all databases, registers and websites, including any filters and limits used. | Search Strategy – Page 8 |
| Selection process | 8 | Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process. | Study Selection – Page 9 |
| Data collection process | 9 | Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process. | Data Extraction – Page 9-10 |
| Data items | 10a | List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect. | Eligibility Criteria – Page 6-8 |
| | 10b | List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information. | Data Extraction – Page 9-10 |

| Section and Topic | Item # | Checklist item | Location where item is reported |
|---|---|---|---|
| Study risk of bias assessment | 11 | Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process. | Certainty in cumulative evidence – Page 10-11 SF-4 |
| Effect measures | 12 | Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results. | Data Synthesis – Page 11-13 |
| Synthesis methods | 13a | Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)). | Results – Page 14 Prisma Flowchart (figure 1) |
| | 13b | Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions. | Data Synthesis – Page 11-13 |
| | 13c | Describe any methods used to tabulate or visually display results of individual studies and syntheses. | Data Synthesis – Page 11-13 |
| | 13d | Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used. | Data Synthesis – Page 11-13 |
| | 13e | Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression). | Data Synthesis – Page 11-13 |
| | 13f | Describe any sensitivity analyses conducted to assess robustness of the synthesized results. | Data Synthesis – Page 11-13 |
| Reporting bias assessment | 14 | Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases). | Certainty in cumulative evidence – Page 10-11 |
| Certainty assessment | 15 | Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome. | Certainty in cumulative evidence – Page 10-11 |
| **RESULTS** | | | |
| Study selection | 16a | Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram. | Results – Page 14-16 |
| | 16b | Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded. | Results – |

| Section and Topic | Item # | Checklist item | Location where item is reported |
|---|---|---|---|
| | | | Page 14 |
| Study characteristics | 17 | Cite each included study and present its characteristics. | Supplementary file 3 |
| Risk of bias in studies | 18 | Present assessments of risk of bias for each included study. | Certainty of evidence assessment – Supplementary file 4 |
| Results of individual studies | 19 | For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots. | Results – Figure 2 |
| Results of syntheses | 20a | For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies. | Results – Page 14-15 |
| | 20b | Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect. | Results – Page 14-15 |
| | 20c | Present results of all investigations of possible causes of heterogeneity among study results. | Results – Page 14-15 |
| | 20d | Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results. | Results – Page 14-15 |
| Reporting biases | 21 | Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed. | Results – Page 14-15 |
| Certainty of evidence | 22 | Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed. | Results – Page 14-15 |
| **DISCUSSION** | | | |
| Discussion | 23a | Provide a general interpretation of the results in the context of other evidence. | Discussion – Page 17-23 |
| | 23b | Discuss any limitations of the evidence included in the review. | Discussion – Page 21-22 |
| | 23c | Discuss any limitations of the review processes used. | Discussion – Page 21-22 |
| | 23d | Discuss implications of the results for practice, policy, and future research. | Practical Application – Page 23 |
| **OTHER INFORMATION** | | | |

| Section and Topic | Item # | Checklist item | Location where item is reported |
|---|---|---|---|
| Registration and protocol | 24a | Provide registration information for the review, including register name and registration number, or state that the review was not registered. | Methods – Page 6 |
| | 24b | Indicate where the review protocol can be accessed, or state that a protocol was not prepared. | Methods – Page 6 |
| | 24c | Describe and explain any amendments to information provided at registration or in the protocol. | Methods – Page 6 |
| Support | 25 | Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review. | Declarations – Page 24 |
| Competing interests | 26 | Declare any competing interests of review authors. | Declarations – Page 24 |
| Availability of data, code and other materials | 27 | Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review. | Declarations – Page 24 |

**Supplementary File 2:** Description of meta-analysis model

All meta-analyses were conducted using a nested four-level mixed effects meta-analytic model. The series of nestings included the individual study (level 4), the outcome (level 3), the measurement occasion (level 2) and the sampling variance (level 1). The meta-analysis model (null model) describing the average effect and variance across each level can be expressed as:

Level1: $d_{ijk} = \beta_{0ijk} + e_{ijk},\qquad e_{ijk} \sim N(0, \sigma_e^2)$

Level2: $\beta_{0ijk} = \eta_{0jk} + r_{ijk},\qquad r_{ijk} \sim N(0, \sigma_r^2)$

Level3: $\eta_{0jk} = \theta_{0k} + u_{0jk},\qquad u_{0jk} \sim N(0, \sigma_u^2)$

Level4: $\theta_{0k} = \gamma_0 + v_{0k},\qquad v_{0k} \sim N(0, \sigma_v^2)$

To give

$$d_{ijk} = \gamma_0 + v_{0k} + u_{0jk} + r_{ijk} + e_{ijk}$$

where $d_{ijk}$ is the observed effect size at measurement occasion $i$ $(i = 1,2, \dots, I_{jk})$, from outcome $j$ $(j = 1,2, \dots, J_k)$ and from study $k$ $(k = 1,2, \dots, K)$. The indexing $I_{jk}$ denotes that the number of measurement occasions may vary across outcomes and studies, and $J_k$ denotes the number of outcomes may vary across studies. The random effects across the different levels $(v_{0k}, u_{0jk}, r_{ijk}, e_{ijk})$ were assumed to be independent such that the variance of an observed effect size was $\sigma^2(d_{ijk}) = \sigma_r^2 + \sigma_u^2 + \sigma_v^2 + \sigma_e^2$. The null model states that the underlying true population average effect size is $\gamma_0$, and for each study the average effect size will equal $\theta_{0k}$, and due to the use of a normal distribution, the value for most studies will lie in the interval $\gamma_0 \pm 2\sigma_v^2$. The true effect sizes for different outcomes within studies, and across measurement occasions within outcomes can then move further from $\theta_{0k}$, based on the magnitude of the variances $\sigma_u^2$ and $\sigma_r^2$. If we consider two observations $d_{ijk}, d_{i'j'k'}$ then the covariance of these are

$$cov(d_{ijk}, d_{i'j'k'}) = cov(v_{0k}, v_{0k'}) + cov(u_{0jk}, u_{0j'k'}) + cov(r_{ijk}, r_{i'j'k'}) + cov(e_{ijk}, e_{i'j'k'}).$$

Which is equal to $\sigma_v^2 + \sigma_u^2 + \sigma_r^2$ (for $i = i', j = j', k = k'$), $\sigma_v^2 + \sigma_u^2$ (for $i \neq i', j = j', k = k'$), and $\sigma_v^2$ (for $i \neq i', j \neq j', k = k'$).

**Supplementary File 3:** References of included studies


1. Abade E, Sampaio J, Santos L, Gonçalves B, Sá P, Carvalho A, Gouveia P, Viana J. Effects of using compound or complex strength-power training during in-season in team sports. *Res Sports Med* 28:371-82, 2020.
2. Abade E, Silva N, Ferreira R, Baptista J, Gonçalves B, Osório S, Viana J. Effects of adding vertical or horizontal force-vector exercises to in-season general strength training on jumping and sprinting performance of youth football players. *J Strength Cond Res* 35:2769-74, 2021.
3. Aloui G, Hermassi S, Hammami M, Cherni Y, Gaamouri N, Shephard RJ, van den Tillaar R, Chelly MS. Effects of Elastic Band Based Plyometric Exercise on Explosive Muscular Performance and Change of Direction Abilities of Male Team Handball Players. *Front Physiol* 11:604983, 2020.
4. Alves JM, Rebelo AN, Abrantes C, Sampaio J. Short-term effects of complex and contrast training in soccer players' vertical jump, sprint, and agility abilities. *J Strength Cond Res* 24:936-41, 2010.
5. Appleby BB, Cormack SJ, Newton RU. Unilateral and bilateral lower-body resistance training does not transfer equally to sprint and change of direction performance. *J Strength Cond Res* 34:54-64, 2020.
6. Arazi H, Khanmohammadi A, Asadi A, Haff GG. The effect of resistance training set configuration on strength, power, and hormonal adaptation in female volleyball players. *Appl Physiol Nutr Metab* 43:154-64, 2018.
7. Asadi A, Ramirez-Campillo R, Meylan C, Nakamura FY, Cañas-Jamett R, Izquierdo M. Effects of volume-based overload plyometric training on maximal-intensity exercise adaptations in young basketball players. *J Sports Med Phys Fitness* 57:1557-63, 2016.
8. Ayers JL, DeBeliso M, Sevene TG, Adams KJ. Hang cleans and hang snatches produce similar improvements in female collegiate athletes. *Biol Sport* 33:251-6, 2016.
9. Barbalho M, Gentil P, Raiol R, Del Vecchio FB, Ramirez-Campillo R, Coswig VS. Non-linear resistance training program induced power and strength but not linear sprint velocity and agility gains in young soccer players. *Sports* 6:43, 2018.
10. Barr MJ, Sheppard JM, Agar-Newman DJ, Newton RU. Transfer effect of strength and power training to the sprinting kinematics of international rugby players. *J Strength Cond Res* 28:2585-96, 2014.
11. Barr MJ, Sheppard JM, Gabbett TJ, Newton RU. Long-term training-induced changes in sprinting speed and sprint momentum in elite rugby union players. *J Strength Cond Res* 28:2724-31, 2014.
12. Bianchi M, Coratella G, Dello Iacono A, Beato M. Comparative effects of single vs. double weekly plyometric training sessions on jump, sprint and change of direction abilities of elite youth football players. *J Sports Med Phys Fitness* 59:910-915, 2019.
13. Blazevich AJ, Gill ND, Bronks R, Newton RU. Training-specific muscle architecture adaptation after 5-wk training in athletes. *Med Sci Sports Exerc* 35:2013-22, 2003.
14. Borges JH, Conceição MS, Vechin FC, Pascoal EH, Silva RP, Borin JP. The effects of resisted sprint vs. plyometric training on sprint performance and repeated sprint ability during the final weeks of the youth soccer season. *Sci Sports* 31:e101-5, 2016.
15. Bouteraa I, Negra Y, Shephard RJ, Chelly MS. Effects of combined balance and plyometric training on athletic performance in female basketball players. *J Strength Cond Res* 34:1967-73, 2020.
16. Branquinho L, Ferraz R, Mendes PD, Petricia J, Serrano J, Marques MC. The effect of an in-season 8-week plyometric training programme followed by a detraining period on explosive skills in competitive junior soccer players. *Montenegrin J Sports Sci Med* 9:33-40, 2020.
17. 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* 40:121-8, 2014.
18. Cahill MJ, Oliver JL, Cronin JB, Clark KP, Cross MR, Lloyd RS. Influence of resisted sled-push training on the sprint force-velocity profile of male high school athletes. *Scand J Med Sci Sports* 30:442-9, 2020.
19. Callister R, Shealy MJ, Fleck SJ, Dudley GA. Performance adaptations to sprint, endurance and both modes of training. *J Strength Cond Res* 2:46-51, 1988.

20. Carlos-Vivas J, Perez-Gomez J, Eriksrud O, Freitas TT, Marín-Cascales E, Alcaraz PE. Vertical versus horizontal resisted sprint training applied to young soccer players: Effects on physical performance. *Int J Sports Physiol Perform* 15:748-58, 2020.
21. Chaabene H, Negra Y, Sammoud S, et al. The Effects of Combined Balance and Complex Training Versus Complex Training Only on Measures of Physical Fitness in Young Female Handball Players. *Int J Sports Physiol Perform* 16:1439-1446, 2021.
22. Chaalali A, Bouriel K, Rouissi M, Chtara M, Mkaouer B, Cronin J, Chaouachi A, Chamari K. Resisted sprint training with partner towing improves explosive force and sprint performance in young soccer players-a pilot study. *Biol Sport* 39:379-87, 2022.
23. Chakshuraksha P, Apanukul S. Effects of Accentuated Eccentric Loading Combined with Plyometric Training on Strength, Power, Speed, and Agility in Male Rugby Players. *J Exerc Physiol Online* 24:21-29, 2021.
24. Chelly MS, Fathloun M, Cherif N, Amar MB, Tabka Z, Van Praagh E. Effects of a back squat training program on leg power, jump, and sprint performances in junior soccer players. *J Strength Cond Res* 23:2241-9, 2009
25. Chelly MS, Ghenem MA, Abid K, Hermassi S, Tabka Z, Shephard RJ. Effects of in-season short-term plyometric training program on leg power, jump-and sprint performance of soccer players. *J Strength Cond Res* 24:2670-6, 2010.
26. 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* 28:1401-10, 2014.
27. Cherni Y, Hammami M, Jelid MC, Aloui G, Suzuki K, Shephard RJ, Chelly MS. Neuromuscular Adaptations and Enhancement of Physical Performance in Female Basketball Players After 8 Weeks of Plyometric Training. *Front Physiol* 11:588787, 2021.
28. Chimera NJ, Swanik KA, Swanik CB, Straub SJ. Effects of plyometric training on muscle-activation strategies and performance in female athletes. *J Athl Train* 39:24-31, 2004.
29. Cin M, Çabuk R, Demirarar O, Özçaldiran B. Cluster Resistance Training Results Higher Improvements on Sprint, Agility, Strength and Vertical Jump in Professional Volleyball Players. *Turkiye Klinikleri J Sports Sci* 13:234-40, 2021.
30. Clark KP, Stearne DJ, Walts CT, Miller AD. The longitudinal effects of resisted sprint training using weighted sleds vs. weighted vests. *J Strength Cond Res* 24:3287-95, 2010.
31. Comfort P, Haigh A, Matthews MJ. Are changes in maximal squat strength during preseason training reflected in changes in sprint performance in rugby league players?. *J Strength Cond Res* 26:772-6, 2012.
32. Coratella G, Beato M, Cè E, Scurati R, Milanese C, Schena F, Esposito F. Effects of in-season enhanced negative work-based vs traditional weight training on change of direction and hamstrings-to-quadriceps ratio in soccer players. *Biol Sport* 36:241-8, 2019.
33. Coratella G, Beato M, Milanese C, Longo S, Limonta E, Rampichini S, Cè E, Bisconti AV, Schena F, Esposito F. Specific adaptations in performance and muscle architecture after weighted jump-squat vs. body mass squat jump training in recreational soccer players. *J Strength Cond Res* 32:921-9, 2018.
34. Corrêa DA, Soares DS, Gonelli PRG, Cesar MdC, Germano MD, Sindorf MAG, et al. Effect of 29 Weeks of Periodized Soccer Training on the Neuromuscular Performance of Soccer Players Under 20 Years of Age. *J Exerc Physiol Online* 19:32-41, 2016.
35. Coutts A, Reaburn P, Piva TJ, Murphy A. Changes in selected biochemical, muscular strength, power, and endurance measures during deliberate overreaching and tapering in rugby league players. *Int J Sports Med* 28:116-24, 2007.
36. Coutts AJ, Murphy AJ, Dascombe BJ. Effect of direct supervision of a strength coach on measures of muscular strength and power in young rugby league players. *J Strength Cond Res* 18:316-323, 2004.
37. Cressey EM, West CA, Tiberio DP, Kraemer WJ, Maresh CM. The effects of ten weeks of lower-body unstable surface training on markers of athletic performance. *J Strength Cond Res* 21:561-7, 2007.
38. Cross MR, Lahti J, Brown SR, Chedati M, Jimenez-Reyes P, Samozino P, Eriksrud O, Morin JB. Training at maximal power in resisted sprinting: Optimal load determination methodology and pilot results in team sport athletes. *PLoS One* 13:e0195477, 2018.

39. de Hoyo M, Gonzalo-Skok O, Sañudo B, Carrascal C, Plaza-Armas JR, Camacho-Candil F, Otero-Esquina C. Comparative effects of in-season full-back squat, resisted sprint training, and plyometric training on explosive performance in U-19 elite soccer players. *J Strength Cond Res* 30:368-77, 2016.
40. de Hoyo M, Pozzo M, Sañudo B, Carrasco L, Gonzalo-Skok O, Domínguez-Cobo S, Morán-Camacho E. Effects of a 10-week in-season eccentric-overload training program on muscle-injury prevention and performance in junior elite soccer players. *Int J Sports Physiol Perform* 10:46-52, 2015.
41. De Hoyo M, Sañudo B, Carrasco L, Domínguez-Cobo S, Mateo-Cortes J, Cadenas-Sánchez MM, Nimphius S. Effects of traditional versus horizontal inertial flywheel power training on common sport-related tasks. *J Hum Kinet* 47:155-67, 2015.
42. Dello Iacono A, Martone D, Milic M, Padulo J. Vertical-vs. horizontal-oriented drop jump training: chronic effects on explosive performances of elite handball players. *J Strength Cond Res* 31:921-31, 2017.
43. Douglas J, Pearson S, Ross A, McGuigan M. Effects of accentuated eccentric loading on muscle properties, strength, power, and speed in resistance-trained rugby players. *J Strength Cond Res* 32:2750-61, 2018.
44. Falk Neto JH, Parent EC, Kennedy MD. Long-Term Athlete Development: Seasonal and Longitudinal Fitness Changes in Female University Rugby Players. *J Strength Cond Res* 35:3459-65, 2021.
45. 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* 31:1460-7, 2013.
46. Feser EH, Bayne H, Loubser I, Bezodis NE, Cronin JB. Wearable resistance sprint running is superior to training with no load for retaining performance in pre-season training for rugby athletes. *Eur J Sport Sci* 21:967-75, 2021.
47. Feser EH, Korfist C, Lindley K, Bezodis NE, Clark K, Cronin J. The effects of lower-limb wearable resistance on sprint performance in high school American football athletes: A nine-week training study. *Int J Sports Sci Coach* 16:1187-95, 2021.
48. Freitas TT, Calleja-González J, Carlos-Vivas J, Marín-Cascales E, Alcaraz PE. Short-term optimal load training vs a modified complex training in semi-professional basketball players. *J Sports Sci* 37:434-42, 2019.
49. Fry AC, Kraemer WJ, Weseman CA, Conroy BP, Gordon SE, Hoffman JR, Maresh CM. The effects of an off-season strength and conditioning program on starters and non-starters in women's intercollegiate volleyball. *J Strength Cond Res* 5:174-81, 1991.
50. Gavanda S, Geisler S, Quittmann OJ, Schiffer T. The effect of block versus daily undulating periodization on strength and performance in adolescent football players. *Int J Sports Physiol Perform* 14:814-21, 2019.
51. Gee TI, Harsley P, Bishop DC. Effect of 10 Weeks of Complex Training on Speed and Power in Academy Soccer Players. *Int J Sports Physiol Perform* 16:1134-9, 2021.
52. Gil S, Barroso R, Crivoi do Carmo E, Loturco I, Kobal R, Tricoli V, Ugrinowitsch C, Roschel H. Effects of resisted sprint training on sprinting ability and change of direction speed in professional soccer players. *J Sports Sci* 36:1923-9, 2018.
53. Gjinovci B, Idrizovic K, Uljevic O, Sekulic D. Plyometric training improves sprinting, jumping and throwing capacities of high level female volleyball players better than skill-based conditioning. *J Sports Sci Med* 16:527-35, 2017.
54. González-Badillo JJ, Pareja-Blanco F, Rodríguez-Rosell D, Abad-Herencia JL, del Ojo-López JJ, Sánchez-Medina L. Effects of velocity-based resistance training on young soccer players of different ages. *J Strength Cond Res* 29:1329-38, 2015.
55. Gonzalo-Skok O, Tous-Fajardo J, Suarez-Arrones L, Arjol-Serrano JL, Casajús JA, Mendez-Villanueva A. Single-leg power output and between-limbs imbalances in team-sport players: Unilateral versus bilateral combined resistance training. *Int J Sports Physiol Perform* 12:106-14, 2017.
56. Gonzalo-Skok O, Tous-Fajardo J, Valero-Campo C, Berzosa C, Bataller AV, Arjol-Serrano JL, Moras G, Mendez-Villanueva A. Eccentric-overload training in team-sport functional performance: constant bilateral vertical versus variable unilateral multidirectional movements. *Int J Sports Physiol Perform* 12:951-8, 2017.

57. Gorostiaga EM, Izquierdo M, Ruesta M, Iribarren J, Gonzalez-Badillo JJ, Ibanez J. Strength training effects on physical performance and serum hormones in young soccer players. *Eur J Appl Physiol* 91:698-707, 2004.
58. Griffiths B, Grant J, Langdown L, Gentil P, Fisher J, Steele J. The effect of in-season traditional and explosive resistance training programs on strength, jump height, and speed in recreational soccer players. *Res Q Exerc Sport* 90:95-102, 2019.
59. Hammami M, Gaamouri N, Aloui G, Shephard RJ, Chelly MS. Effects of a complex strength-training program on athletic performance of junior female handball players. *Int J Sports Physiol Perform* 14:163-9, 2019.
60. Hammami M, Gaamouri N, Shephard RJ, Chelly MS. Effects of contrast strength vs. plyometric training on lower-limb explosive performance, ability to change direction and neuromuscular adaptation in soccer players. *J Strength Cond Res* 33:2094-103, 2019
61. Hammami M, Negra Y, Billaut F, Hermassi S, Shephard RJ, Chelly MS. Effects of lower-limb strength training on agility, repeated sprinting with changes of direction, leg peak power, and neuromuscular adaptations of soccer players. *J Strength Cond Res* 32:37-47, 2018.
62. Hammami M, Negra Y, Shephard RJ, Chelly MS. The effect of standard strength vs. contrast strength training on the development of sprint, agility, repeated change of direction, and jump in junior male soccer players. *J Strength Cond Res* 31:901-12, 2017.
63. Harries SK, Lubans DR, Buxton A, MacDougall TH, Callister R. Effects of 12-week resistance training on sprint and jump performances in competitive adolescent rugby union players. *J Strength Cond Res* 32:2762-9, 2018.
64. Harris GR, Stone MH, O'bryant HS, Proulx CM, Johnson RL. Short-term performance effects of high power, high force, or combined weight-training methods. *J Strength Cond Res* 14:14-20, 2000
65. Harris NK, Cronin JB, Hopkins WG, Hansen KT. Squat jump training at maximal power loads vs. heavy loads: effect on sprint ability. *J Strength Cond Res* 22:1742-9, 2008.
66. Helland C, Hole E, Iversen E, Olsson MC, Seynnes O, Solberg PA, et al. Training Strategies to Improve Muscle Power: Is Olympic-style Weightlifting Relevant?. *Medicine and science in sports and exercise* 49:736-745, 2017.
67. Hennessy LC, Watson AW. The interference effects of training for strength and endurance simultaneously. *J Strength Cond Res* 8:12-9, 1994.
68. Hermassi S, Chelly MS, Tabka Z, Shephard RJ, Chamari K. Effects of 8-week in-season upper and lower limb heavy resistance training on the peak power, throwing velocity, and sprint performance of elite male handball players. *J Strength Cond Res* 25:2424-33, 2011.
69. Hermassi S, Laudner K, Schwesig R. The effects of circuit strength training on the development of physical fitness and performance-related variables in handball players. *J Hum Kinet* 71:191-203, 2020.
70. Hermassi S, Schwesig R, Aloui G, Shephard RJ, Chelly MS. Effects of short-term in-season weightlifting training on the muscle strength, peak power, sprint performance, and ball-throwing velocity of male handball players. *J Strength Cond Res* 33:3309-21, 2019.
71. Hoffman JR, Cooper J, Wendell M, Kang J. Comparison of Olympic vs. traditional power lifting training programs in football players. *J Strength Cond Res* 18:129-35, 2004.
72. Hoffman JR, Kraemer WJ, Fry AC, Deschenes M, Kemp M. The effects of self-selection for frequency of training in a winter conditioning program for football. *J Strength Cond Res* 4:76-82, 1990.
73. Hoffman JR, Ratamess NA, Cooper JJ, Kang JI. Comparison of loaded and unloaded jump squat training on strength/power performance in college football players. *J Strength Cond Res* 19:810-15, 2005.
74. Horwath O, Paulsen G, Esping T, Seynnes O, Olsson MC. Isokinetic resistance training combined with eccentric overload improves athletic performance and induces muscle hypertrophy in young ice hockey players. *J Sci Med Sport* 22:821-6, 2019.
75. Idrizovic K, Gjinovci B, Sekulic D, Uljevic O, João PV, Spasic M, Sattler T. The effects of 3-month skill-based and plyometric conditioning on fitness parameters in junior female volleyball players. *Pediatr Exerc Sci* 30:353-63, 2018.
76. Impellizzeri FM, Rampinini E, Castagna C, Martino F, Fiorini S, Wisloff U. Effect of plyometric training on sand versus grass on muscle soreness and jumping and sprinting ability in soccer players. *Br J Sports Med* 42:42-6, 2008.

77. Ishida A, Travis SK, Stone MH. Short-Term Periodized Programming May Improve Strength, Power, Jump Kinetics, and Sprint Efficiency in Soccer. *J Funct Morphol Kinesiol* 6:45, 2021.
78. Johnson AW, Eastman CS, Feland JB, Mitchell UH, Mortensen BB, Eggett D. Effect of high-speed treadmill training with a body weight support system in a sport acceleration program with female soccer players. *J Strength Cond Res* 27:1496-502, 2013.
79. Kargarfard M, Tajvand S, Rabbani A, Clemente FM, Jalilvand F. Effects of Combined Plyometric and Speed Training on Change of Direction, Maximal Speed, and Repeated Sprint Ability in Young Soccer Players. *Kinesiology* 52:85-93, 2020.
80. Karsten B, Larumbe-Zabala E, Kandemir G, Hazir T, Klose A, Naclerio F. The effects of a 6-week strength training on critical velocity, anaerobic running distance, 30-M sprint and Yo-Yo intermittent running test performances in male soccer players. *PloS One* 11:e0151448, 2016.
81. Kawamori N, Newton RU, Hori N, Nosaka K. Effects of weighted sled towing with heavy versus light load on sprint acceleration ability. *J Strength Cond Res* 28:2738-45, 2014.
82. Klnç F. An intensive combined training program modulates physical, physiological, biomotoric, and technical parameters in women basketball players. *J Strength Cond Res* 22:1769-78, 2008.
83. Kotzamanidis C, Chatzopoulos DI, Michailidis C, Papaiakovou G, Patikas DI. The effect of a combined high-intensity strength and speed training program on the running and jumping ability of soccer players. *J Strength Cond Res* 19:369-75, 2005.
84. Koundourakis NE, Androulakis N, Spyridaki EC, Castanas E, Malliaraki N, Tsatsanis C, Margioris AN. Effect of different seasonal strength training protocols on circulating androgen levels and performance parameters in professional soccer players. *Hormones* 13:104-18, 2014.
85. Lahti J, Jiménez-Reyes P, Cross MR, Samozino P, Chassaing P, Simond-Cote B, Ahtiainen JP, Morin JB. Individual sprint force-velocity profile adaptations to in-season assisted and resisted velocity-based training in professional rugby. *Sports* 8:74, 2020.
86. Lievens M, Bourgois JG, Boone J. Periodization of Plyometrics: Is There an Optimal Overload Principle?. *J Strength Cond Res* 35:2669-76, 2021.
87. Lockie RG, Murphy AJ, Callaghan SJ, Jeffriess MD. Effects of sprint and plyometrics training on field sport acceleration technique. *J Strength Cond Res* 28:1790-801, 2014.
88. Lockie RG, Murphy AJ, Schultz AB, Knight TJ, de Jonge XA. The effects of different speed training protocols on sprint acceleration kinematics and muscle strength and power in field sport athletes. *J Strength Cond Res* 26:1539-50, 2012
89. Lockie RG, Schultz AB, Callaghan SJ, Jeffriess MD. The effects of traditional and enforced stopping speed and agility training on multidirectional speed and athletic function. *J Strength Cond Res* 28:1538-51, 2014.
90. López-Segovia M, Andrés JM, González-Badillo JJ. Effect of 4 months of training on aerobic power, strength, and acceleration in two under-19 soccer teams. *J Strength Cond Res* 24:2705-14, 2010.
91. Los Arcos A, 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* 9:480-8, 2014.
92. 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* 27:1791-7, 2013.
93. Loturco I, Nakamura FY, Kobal R, Gil S, Abad CC, Cuniyochi R, Pereira LA, Roschel H. Training for power and speed: Effects of increasing or decreasing jump squat velocity in elite young soccer players. *J Strength Cond Res* 29:2771-9, 2015.
94. Loturco I, Pereira LA, Kobal R, Zanetti V, Gil S, Kitamura K, Abad CC, Nakamura FY. Half-squat or jump squat training under optimum power load conditions to counteract power and speed decrements in Brazilian elite soccer players during the preseason. *J Sports Sci* 33:1283-92, 2015.
95. Loturco I, Pereira LA, Kobal R, Maldonado T, Piazzi AF, Bottino A, Kitamura K, Cal Abad CC, de Arruda M, Nakamura FY. Improving sprint performance in soccer: effectiveness of jump squat and Olympic push press exercises. *PloS One* 11:e0153958, 2016.
96. Loturco I, Pereira LA, Reis VP, Bishop C, Zanetti V, Alcaraz PE, Freitas TT, Mcguigan MR. Power training in elite young soccer players: Effects of using loads above or below the optimum power zone. *J Sports Sci* 38:1416-22, 2020.

97. Luteberget LS, Raastad T, Seynnes O, Spencer M. Effect of traditional and resisted sprint training in highly trained female team handball players. *Int J Sports Physiol Perform* 10:642-7, 2015.
98. Lyttle AD, Wilson GJ, Ostrowski KJ. Enhancing performance: maximal power versus combined weights and plyometrics training. *J Strength Cond Res* 10:173-179, 1996.
99. Manolopoulos E, Papadopoulos C, Salonikidis K, Katartzi E, Poluha S. Strength training effects on physical conditioning and instep kick kinematics in young amateur soccer players during preseason. *Percept Mot Skills* 99:701-10, 2004.
100. Manouras N, Papanikolaou Z, Karatrantou K, Kouvarakis P, Gerodimos V. The efficacy of vertical vs. horizontal plyometric training on speed, jumping performance and agility in soccer players. *Int J Sports Sci Coach* 11:702-9, 2016.
101. Maroto-Izquierdo S, García-López D, de Paz JA. Functional and muscle-size effects of flywheel resistance training with eccentric-overload in professional handball players. *J Hum Kinet* 60:133-43, 2017.
102. Marques DL, Travassos B, Sousa AC, Gil MH, Ribeiro JN, Marques MC. Effects of low-moderate load high-velocity resistance training on physical performance of under-20 futsal players. *Sports* 7:69., 2019.
103. Marzouki H, Ouergui I, Doua N, Gmada N, Bouassida A, Bouhlel E. Effects of 1 vs. 2 sessions per week of equal-volume sprint training on explosive, high-intensity and endurance-intensive performances in young soccer players. *Biol Sport* 38:175-83, 2021.
104. McBride JM, Triplett-McBride T, Davie A, Newton RU. The effect of heavy-vs. light-load jump squats on the development of strength, power, and speed. *J Strength Cond Res* 16:75-82, 2002
105. McMaster D, Gill N, McGuigan M, Cronin J. Effects of Complex Strength and Ballistic Training on Maximum Strength, Sprint Ability and Force-Velocity-Power Profiles of Semi-Professional Rugby Union Players. *J Aus Strength Cond* 22:17-30, 2014.
106. McMorrow BJ, Ditroilo M, Egan B. Effect of heavy resisted sled sprint training during the competitive season on sprint and change-of-direction performance in professional soccer players. *Int J Sports Physiol Perform* 14:1066-73, 2019.
107. Miranda C, Rago V, Silva JR, Rebelo A. Effects of traditional vs. complex strength training added to regular football training on physical capacities in U19 football players: a team study. *Sport Sci Health* 1, 2021. https://doi.org/10.1007/s11332-021-00833-9.
108. Moir G, Sanders R, Button C, Glaister M. The effect of periodized resistance training on accelerative sprint performance. *Sports Biomech* 6:285-300, 2007.
109. Moore EW, Hickey MS, Raoul FR. Comparison of Two Twelve Week Off-Season Combined Training Programs On Entry Level Collegiate Soccer Players' Performance. *J Strength Cond Res* 19:791-8, 2005.
110. Morin JB, Petrakos G, Jiménez-Reyes P, Brown SR, Samozino P, Cross MR. Very-heavy sled training for improving horizontal-force output in soccer players. *Int J Sports Physiol Perform* 12:840-4, 2017.
111. Mujika I, Santisteban J, Castagna C. In-season effect of short-term sprint and power training programs on elite junior soccer players. *J Strength Cond Res* 23:2581-7, 2009.
112. Mulcahy RL, Crowther RG. The effects of an 8 week supplemented plyometric exercise training program on leg power, agility and speed in adolescent netball players. *J Aus Strength Cond* 21:28-33, 2013.
113. Nikolic D, Beric D, Kocic M, Daskalovski B. Complex training and sprint abilities of young basketball players. *Facta Univ Ser Phys Educ Sport* 15:025-36, 2017.
114. Orange ST, Metcalfe JW, Robinson A, Applegarth MJ, Liefeith A. Effects of in-season velocity-versus percentage-based training in academy rugby league players. *Int J Sports Physiol Perform* 15:554-61, 2019.
115. Otero-Esquina C, de Hoyo Lora M, Gonzalo-Skok Ó, Domínguez-Cobo S, Sánchez H. Is strength-training frequency a key factor to develop performance adaptations in young elite soccer players?. *Eur J Sport Sci* 17:1241-51, 2017.
116. Ozbar N, Ates S, Agopyan A. The effect of 8-week plyometric training on leg power, jump and sprint performance in female soccer players. *J Strength Cond Res* 28:2888-94, 2014.
117. Parnow A, Derakhshandeh S, Hosseini A. The Effect of 4-week Difference Training Methods on Some Fitness Variables in Youth Handball Players. *Int J Appl Exerc Physiol* 5:46-56, 2016.

118.Paz-Franco A, Rey E, Barcala-Furelos R. Effects of 3 different resistance training frequencies on jump, sprint, and repeated sprint ability performances in professional futsal players. *J Strength Cond Res* 31:3343-50, 2017.
119.Pedersen S, Heitmann KA, Sagelv EH, Johansen D, Pettersen SA. Improved maximal strength is not associated with improvements in sprint time or jump height in high-level female football players: a cluster-randomized controlled trial. *BMC Sports Sci Med Rehabilitation* 11:1-8, 2019.
120.Pienaar C, Coetzee B. Changes in selected physical, motor performance and anthropometric components of university-level rugby players after one microcycle of a combined rugby conditioning and plyometric training program. *J Strength Cond Res* 27:398-415, 2013.
121.Prieto MF, González JR, de Villarreal Sáez ES, Palma JR, García FJ, Fernández FT. Effects of combined plyometric and sled training on vertical jump and linear speed performance in young soccer players. *Retos: nuevas tendencias en educación física, deporte y recreación* 42:228-35, 2021.
122.Rakovic E, Paulsen G, Helland C, Eriksrud O, Haugen T. The effect of individualised sprint training in elite female team sport athletes: A pilot study. *J Sports Sci* 36:2802-8, 2018.
123.Randell AD, Cronin JB, Keogh JW, Gill ND, Pedersen MC. Effect of instantaneous performance feedback during 6 weeks of velocity-based resistance training on sport-specific performance tests. *J Strength Cond Res* 25:87-93, 2011.
124.Rey E, Padrón-Cabo A, Fernández-Penedo D. Effects of sprint training with and without weighted vest on speed and repeated sprint ability in male soccer players. *J Strength Cond Res* 31:2659-66, 2017.
125.Rhea MR, Kenn JG, Peterson MD, Massey D, Simão R, Marin PJ, Favero M, Cardozo D, Krein D. Joint-angle specific strength adaptations influence improvements in power in highly trained athletes. *Hum Mov* 17:43-9, 2016.
126.Ribeiro J, Teixeira L, Lemos R, Teixeira AS, Moreira V, Silva P, Nakamura FY. Effects of plyometric versus optimum power load training on components of physical fitness in young male soccer players. *Int J Sports Physiol Perform* 15:222-30, 2020.
127.Rodríguez-Osorio D, Gonzalo-Skok O, Pareja-Blanco F. Effects of Resisted Sprints With Changes of Direction Through Several Relative Loads on Physical Performance in Soccer Players. *Int J Sports Physiol Perform* 14:1022-8, 2019.
128.Rodríguez-Rosell D, Franco-Márquez F, Mora-Custodio R, González-Badillo JJ. Effect of high-speed strength training on physical performance in young soccer players of different ages. *J Strength Cond Res* 31:2498-508, 2017.
129.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* 20:695-9, 2017.
130.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* 22:773-80, 2008.
131.Sabido R, Hernández-Davó JL, Botella J, Navarro A, Tous-Fajardo J. Effects of adding a weekly eccentric-overload training session on strength and athletic performance in team-handball players. *Eur J Sport Sci* 17:530-8, 2017.
132.Sagelv EH, Pedersen S, Nilsen LP, Casolo A, Welde B, Randers MB, Pettersen SA. Flywheel squats versus free weight high load squats for improving high velocity movements in football. A randomized controlled trial. *BMC Sports Sci Med Rehabilitation* 12:1-3, 2020.
133.Sanchez-Sanchez J, Ramirez-Campillo R, Petisco C, Hernandez D, Nakamura FY. Effects of short-term strength and jumping exercises distribution on soccer player's physical fitness. *Kinesiology* 53:236-44, 2021.
134.Sander A, Keiner M, Wirth K, Schmidtbleicher D. Influence of a 2-year strength training programme on power performance in elite youth soccer players. *Eur J Sport Sci* 13:445-51, 2013.
135.Seitz LB, Barr M, Haff GG. Effects of sprint training with or without ball carry in elite rugby players. *Int J Sports Physiol Perform* 10:761-6, 2015.
136.Shalfawi SA, Haugen T, Jakobsen TA, Enoksen E, Tønnessen E. The effect of combined resisted agility and repeated sprint training vs. strength training on female elite soccer players. *J Strength Cond Res* 27:2966-72, 2013.

137.Siegler J, Gaskill S, Ruby B. Changes evaluated in soccer-specific power endurance either with or without a 10-week, in-season, intermittent, high-intensity training protocol. *J Strength Cond Res* 17:379-87, 2003.
138.Speirs DE, Bennett MA, Finn CV, Turner AP. Unilateral vs. bilateral squat training for strength, sprints, and agility in academy rugby players. *J Strength Cond Res* 30:386-92, 2016.
139.Spinks CD, Murphy AJ, Spinks WL, Lockie RG. The effects of resisted sprint training on acceleration performance and kinematics in soccer, rugby union, and Australian football players. *J Strength Cond Res* 21:77-85, 2007.
140.Stern D, Gonzalo-Skok O, Loturco I, Turner A, Bishop C. A comparison of bilateral vs. unilateral-biased strength and power training interventions on measures of physical performance in elite youth soccer players. *J Strength Cond Res* 34:2105-11, 2020.
141.Styles WJ, Matthews MJ, Comfort P. Effects of strength training on squat and sprint performance in soccer players. *J Strength Cond Res* 30:1534-9, 2016.
142.Talpey SW, Young WB, Saunders N. Is nine weeks of complex training effective for improving lower body strength, explosive muscle function, sprint and jumping performance?. *Int J Sports Sci Coach* 11:736-45, 2016.
143.Thomas K, French D, Hayes PR. The effect of two plyometric training techniques on muscular power and agility in youth soccer players. *J Strength Cond Res* 23:332-5, 2009.
144.Till K, Darrall-Jones J, Weakley JJ, Roe GA, Jones BL. The influence of training age on the annual development of physical qualities within academy rugby league players. *J Strength Cond Res* 31:2110-8, 2017.
145.Tønnessen E, Shalfawi SA, Haugen T, Enoksen E. The effect of 40-m repeated sprint training on maximum sprinting speed, repeated sprint speed endurance, vertical jump, and aerobic capacity in young elite male soccer players. *J Strength Cond Res* 25:2364-70, 2011.
146.Torres-Torrelo J, Rodríguez-Rosell D, González-Badillo JJ. Light-load maximal lifting velocity full squat training program improves important physical and skill characteristics in futsal players. *J Sports Sci* 35:967-75, 2017.
147.Tsimachidis C, Patikas D, Galazoulas C, Bassa E, Kotzamanidis C. The post-activation potentiation effect on sprint performance after combined resistance/sprint training in junior basketball players. *J Sports Sci* 31:1117-24, 2013.
148.Vadivelan K, Sudhakar S. To compare the effects of sprint and plyometric training program on anaerobic power and agility in collegiate male football players. *Int J Physio* 2:535-43, 2015.
149.Voelzke M, Stutzig N, Thorhauer HA, Granacher U. Promoting lower extremity strength in elite volleyball players: effects of two combined training methods. *J Sci Med Sport* 15:457-62, 2012.
150.Weakley J, Till K, Sampson J, Banyard H, Leduc C, Wilson K, Roe G, Jones B. The effects of augmented feedback on sprint, jump, and strength adaptations in rugby union players after a 4-week training program. *Int J Sports Physiol Perform* 14:1205-11, 2019.
151.Weakley JJ, Till K, Darrall-Jones J, Roe GA, Phibbs PJ, Read DB, Jones BL. Strength and conditioning practices in adolescent rugby players: Relationship with changes in physical qualities. *J Strength Cond Res* 33:2361-9, 2019.
152.Wirtz N, Zinner C, Doermann U, Kleinoeder H, Mester J. Effects of Loaded Squat Exercise with and without Application of Superimposed EMS on Physical Performance. *J Sports Sci Med* 15:26-33, 2016.
153.Yanci J, Castillo D, Iturricastillo A, Ayarra R, Nakamura FY. Effects of two different volume-equated weekly distributed short-term plyometric training programs on futsal players' physical performance. *J Strength Cond Res* 31:1787-94, 2017.
154.Yanci J, Los Arcos A, Camara J, Castillo D, García A, Castagna C. Effects of horizontal plyometric training volume on soccer players' performance. *Res Sports Med* 24:308-19, 2016.
155.Yáñez-García JM, Rodríguez-Rosell D, Mora-Custodio R, González-Badillo JJ. Changes in muscle strength, jump, and sprint performance in young elite basketball players: The impact of combined high-speed resistance training and plyometrics. *J Strength Cond Res* 36:478-85, 2022.
156.Zabaloy S, Pareja-Blanco F, Giráldez JC, Rasmussen JI, González JG. Effects of individualised training programmes based on the force-velocity imbalance on physical performance in rugby players. *Isokinet Exerc Sci* 28:181-90, 2020.
157.Zafeiridis A, Saraslanidis P, Manou V, Ioakimidis P. The effects of resisted sled-pulling sprint training on acceleration and maximum speed performance. *J Sports Med Phys Fitness* 45:284-90, 2005.

**Supplementary File 4:** Certainty of Evidence Assessment

*Sprint meta-analysis outcomes*

| Category | Analysis | Overall RoB | Inconsistency | Imprecision | Small study-effects | Certainty |
|---|---|---|---|---|---|---|
| **Sprint** | Time (691 outcomes / 141 studies) + Velocity (131 outcomes / 27 studies) | High risk | High risk | Low risk | High risk | Very low |
| **Sprint** | Time (691 outcomes / 141 studies) | High risk | High risk | Low risk | High risk | Very low |
| **Sprint** | Velocity (131 outcomes / 27 studies) | High risk | High risk | Low risk | High risk | Very low |
| **Sprint** | Distance ≤10 m (290 outcomes / 113 studies) | High risk | High risk | Low risk | Low risk | Low |
| **Sprint** | Distance ≤20 m (185 outcomes / 92 studies) | High risk | Low risk | Low risk | High risk | Low |
| **Sprint** | Distance ≤30 m (96 outcomes / 50 studies) | High risk | Low risk | High risk | Low risk | Low |
| **Sprint** | Distance ≤40 m (80 outcomes / 35 studies) | High risk | High risk | High risk | High risk | Very low |
| **Sprint** | Sprint training (232 outcomes / 29 studies) | High risk | Low risk | Low risk | Low risk | Moderate |
| **Sprint** | Strength training (263 outcomes / 62 studies) | High risk | High risk | Low risk | High risk | Very low |
| **Sprint** | Plyometric training (65 outcomes / 24 studies) | High risk | Low risk | High risk | Low risk | Low |
| **Sprint** | Combined training (262 outcomes / 66 studies) | High risk | High risk | Low risk | High risk | Very low |
| **Sprint** | Low intensity (200 outcomes / 45 studies) | High risk | High risk | Low risk | High risk | Very low |
| **Sprint** | High intensity | High risk | High risk | High risk | High risk | Very low |

| | | | | | | |
|---|---|---|---|---|---|---|
| | (190 outcomes / 45 studies) | | | | | |
| **Sprint** | Low volume (665 outcomes / 132 studies) | High risk | High risk | Low risk | High risk | Very low |
| **Sprint** | High volume (155 outcomes / 36 studies) | High risk | Low risk | Low risk | Low risk | Moderate |
| **Sprint** | <8 Weeks (330 outcomes / 70 studies) | High risk | Low risk | Low risk | Low risk | Moderate |
| **Sprint** | ≥8 Weeks (492 outcomes / 93 studies) | High risk | High risk | Low risk | High risk | Very low |
| **Sprint** | Novice (255 outcomes / 59 studies) | High risk | High risk | Low risk | High risk | Very low |
| **Sprint** | Intermediate (430 outcomes / 82 studies) | High risk | High risk | Low risk | Low risk | Low |
| **Sprint** | Advanced (125 outcomes / 18 studies) | High risk | Low risk | Low risk | Low risk | Moderate |
| **Sprint** | Free sprint (111 outcomes / 22 studies) | High risk | Low risk | Low risk | Low risk | Moderate |
| **Sprint** | Resisted sprint (113 outcomes / 21 studies) | High risk | Low risk | Low risk | Low risk | Moderate |

*Strength, power and jump meta-analysis outcomes*

| **Category** | **Analysis** | **Overall RoB** | **Inconsistency** | **Imprecision** | **Small study-effects** | **Certainty** |
|---|---|---|---|---|---|---|
| **Strength** | All outcomes (318 outcomes / 82 studies) | High risk | Low risk | Low risk | High risk | Low |
| **Power** | All outcomes (229 outcomes / 56 studies) | High risk | Low risk | Low risk | Low risk | Moderate |
| **Jump** | All outcomes (424 outcomes / 118 studies) | High risk | Low risk | Low risk | High risk | Low |

**Supplementary File 5:** Risk of bias of individual studies using the PEDro scale

| | | Criterion | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Study** | **Author/Year** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** |
| 1 | Abade, 2020 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 |
| 2 | Abade, 2021 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 3 | Aloui, 2020 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 4 | Alves, 2010 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 5 | Appleby, 2020 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 6 | Arazi, 2018 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 7 | Asadi, 2016 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 8 | Ayers, 2016 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 9 | Barbalho, 2018 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 |
| 10 | Barr, 2014a | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 |
| 11 | Barr, 2014b | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 12 | Bianchi, 2019 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 13 | Blazevich, 2003 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 14 | Borges, 2016 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 15 | Bouteraa, 2020 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 16 | Branquinho, 2020 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 17 | Brito, 2014 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 18 | Cahill, 2020 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 19 | Callister, 1988 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 20 | Carlos-Vivas, 2020 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 21 | Chaabene, 2021 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 |
| 22 | Chaalali, 2022 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 23 | Chakshuraksha, 2021 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 24 | Chelly, 2009 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 25 | Chelly, 2010 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 26 | Chelly, 2014 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 27 | Cherni, 2021 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 28 | Chimera, 2004 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 29 | Cin, 2021 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 30 | Clark, 2010 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 31 | Comfort, 2012 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 |
| 32 | Coratella, 2019 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 33 | Coratella, 2018 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 34 | Corrêa, 2016 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 35 | Coutts, 2007 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 |
| 36 | Coutts, 2004 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 37 | Cressey, 2007 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 38 | Cross, 2018 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 39 | de Hoyo, 2016 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 40 | de Hoyo, 2015a | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| 41 | De Hoyo, 2015b | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 42 | Dello, 2017 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 43 | Douglas, 2018 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 44 | Falk Neto, 2021 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 45 | Faude, 2013 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 46 | Feser, 2021a | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 47 | Feser, 2021b | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 48 | Freitas, 2019 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 49 | Fry, 1991 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 50 | Gavanda, 2019 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 51 | Gee, 2021 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 52 | Gil, 2018 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 53 | Gjinovci, 2017 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 54 | González-Badillo, 2015 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 55 | Gonzalo-Skok, 2017a | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 56 | Gonzalo-Skok, 2017b | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 57 | Gorostiaga, 2004 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 58 | Griffiths, 2019 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 59 | Hammami, 2019a | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 60 | Hammami, 2019b | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 61 | Hammami, 2018 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 62 | Hammami, 2017 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 63 | Harries, 2018 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 |
| 64 | Harris, 2000 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 65 | Harris, 2008 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 66 | Helland, 2017 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 67 | Hennessy, 1994 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 68 | Hermassi, 2011 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 69 | Hermassi, 2020 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 70 | Hermassi, 2019 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 71 | Hoffman, 2004 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 72 | Hoffman, 1990 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 73 | Hoffman, 2005 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 74 | Horwath, 2019 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 75 | Idrizovic, 2018 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 76 | Impellizzeri, 2008 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 77 | Ishida, 2021 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 78 | Johnson, 2013 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 79 | Kargarfard, 2020 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 80 | Karsten, 2016 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 81 | Kawamori, 2014 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 82 | Klnç, 2008 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 83 | Kotzamanidis, 2005 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 84 | Koundourakis, 2014 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 85 | Lahti, 2020 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 86 | Lievens, 2021 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 87 | Lockie, 2014 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 88 | Lockie, 2012 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| 89 | Lockie, 2014 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 90 | López-Segovia, 2010 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 91 | Los Arcos, 2014 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 92 | Loturco, 2013 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 93 | Loturco, 2015a | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 94 | Loturco , 2015b | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 95 | Loturco, 2016 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 96 | Loturco, 2020. | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 97 | Luteberget, 2015 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 98 | Lyttle, 1996 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 99 | Manolopoulos, 2004 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 100 | Manouras, 2016 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 101 | Maroto-Izquierdo, 2017 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 102 | Marques, 2019 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 103 | Marzouki, 2021 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 104 | McBride, 2002 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 105 | McMaster, 2014 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 106 | McMorrow, 2019 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 107 | Miranda, 2021 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 108 | Moir, 2007 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 109 | Moore, 2005 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 110 | Morin, 2017 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 111 | Mujika, 2009 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 112 | Mulcahy, 2013 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 113 | Nikolic, 2017 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 114 | Orange, 2019 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 115 | Otero-Esquina, 2017 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 116 | Ozbar, 2014 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 117 | Parnow, 2016 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 118 | Paz-Franco, 2017 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 119 | Pedersen, 2019 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 120 | Pienaar , 2013 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 121 | Prieto, 2021 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 |
| 122 | Rakovic, 2018 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 123 | Randell, 2011 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 |
| 124 | Rey, 2017 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 125 | Rhea, 2016 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 126 | Ribeiro, 2020 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 127 | Rodríguez-Osorio, 2019 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 128 | Rodríguez-Rosell, 2017a | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 129 | Rodríguez-Rosell, 2017b | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 130 | Ronnestad, 2008 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 131 | Sabido, 2017 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 132 | Sagelv, 2020 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 133 | Sanchez-Sanchez, 2021 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 |
| 134 | Sander, 2013 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 135 | Seitz, 2015 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 136 | Shalfawi, 2013 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 137 | Siegler, 2003 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 138 | Speirs, 2016 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 139 | Spinks, 2007 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 140 | Stern, 2020 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 141 | Styles, 2016 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 142 | Talpey, 2016 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 143 | Thomas, 2009 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 144 | Till, 2017 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 |
| 145 | Tønnessen, 2011 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 146 | Torres-Torrelo, 2017 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 147 | Tsimachidis, 2013 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 148 | Vadivelan, 2015 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 149 | Voelzke, 2012 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 150 | Weakley, 2019a | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 151 | Weakley, 2019b | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 152 | Wirtz, 2016 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 153 | Yanci, 2017 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 154 | Yanci, 2016 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 155 | Yáñez-García, 2022 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 156 | Zabaloy, 2020 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 |
| 157 | Zafeiridis, 2005 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |

**Criterion**

1. eligibility criteria were specified
2. subjects were randomly allocated to groups (in a crossover study, subjects were randomly allocated an order in which treatments were received)
3. Allocation was concealed
4. The groups were similar at baseline regarding the most important prognostic indicators
5. There was blinding of all subjects
6. There was blinding of all therapists who administered the therapy
7. There was blinding of all assessors who measured at least one key outcome
8. Measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups
9. All subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analysed by "intention to treat"
10. The results of between-group statistical comparisons are reported for at least one key outcome
11. The study provides both point measures and measures of variability for at least one key outcome