Reactive Strength Index and its Associations to Measures of Physical and Sports Performance: A Systematic Review with Meta-Analysis

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Running-head:
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All authors contributed to the initial development of the review, search criteria and collectively interpreted the results of the systematic review and meta-analysis. PJ and CB contributed to the implementation of the search strategy and application of the inclusion/exclusion criteria and quality scoring. PJ carried out the meta-analysis with assistance from AT, PR, and CB. PJ drafted the manuscript and all authors contributed to editing and revising the manuscript and approved the final version prior to submission.

Data Availability Statement:

The data within this systematic review and meta-analysis are secondary data and available through the relevant articles referenced throughout. All statistical analyses were carried out using Jamovi, an open source software that is freely available.

ABSTRACT

Background

Reactive strength index (RSI) is used frequently in the testing and monitoring of athletes. Associations with sports performance measures may vary dependent on the task but a literature synthesis has not been performed.

Objectives

The aim of this meta-analysis was to examine associations between RSI measured during rebound jumping tasks and measures of strength, linear and change of direction speed, and endurance performance.

Methods

A systematic literature search with meta-analysis was conducted using databases PubMed, SPORTDiscus, Web of Science, and Ovid. Inclusion criteria required studies to: 1) examine the relationship between RSI and an independent measure of physical or sporting performance for at least one variable; and 2) provide rebound test instructions to minimise ground contact time and maximise displacement of the jump. Methodological quality was assessed using a modified version of the Downs and Black Quality Index tool. Heterogeneity was examined via the Q statistic and I^2. Pooled effect sizes were calculated using a random-effects model, with Egger's regression test used to assess small study bias (inclusive of publication bias).

Results

Of the 1320 citations reviewed, a total of 32 studies were included in this meta-analysis. RSI was significantly and moderately associated to strength (isometric: r = 0.356 [95% CI: 0.209, 0.504]; isotonic: r = 0.365 [0.075, 0.654]; pooled strength measures: r = 0.339 [0.209, 0.469]) and endurance performance (r = 0.401 [0.173, 0.629]). Significant moderate and negative associations were indicated for acceleration (r = -0.426 [-0.562, -0.290]), top speed (r = -0.326 [-0.502, -0.151]), and significant large negative associations were noted for change of direction speed (r = -0.565 [-0.726, -0.404]). Heterogeneity was trivial to moderate across all measures (I^2 = 0 - 66%), and significant for isotonic strength and change of direction speed ($p < 0.1$). Evidence of small study bias was apparent for both acceleration and change of direction speed ($p < 0.05$).

Conclusions

We identified primarily moderate associations between RSI and independent measures of physical and sporting performance, and the strength of these relationships varied based on the task and physical quality assessed. The findings from this meta-analysis can help practitioners to develop more targeted testing and monitoring processes. Future research may wish to examine if associations are stronger in tasks which display greater specificity.

KEY POINTS

- Measures of physical and sporting performance are moderately (strength, speed, endurance performance) and largely (change of direction speed) associated to RSI.
- Large discrepancies exist concerning testing strategies for RSI, with variations reported for jump type, box drop height, equation used to calculate RSI, and units of measurement, indicating a need for consistency in approach to measuring RSI.
- At present no valid and reliable measure of RSI acquired horizontally exists, which may provide a more sport-specific measure relative to tasks such as speed.

1. INTRODUCTION

Reactive strength represents an individuals ability to effectively utilise the stretch shortening cycle (SSC), which is commonly referred to as the ability of the the musculotendinous unit to produce a rapid and powerful concentric contraction, immediately following a rapid eccentric action [1-9]. This typically occurs in movements where body segments are exposed to impact forces that induce stretch [1,9]. The magnitude of impact or stretch forces, task constraints, and the individual's capacity to tolerate such forces, will dictate the nature of the SSC (i.e., fast ≤ 250 ms or slow > 250 ms) [10]. This can be evidenced across sporting tasks such as cutting [11], sprinting [12], and jumping [13,14]. Alterations in reactive strength are associated primarily with changes in the stretch rate (via a more rapid eccentric/concentric muscle action) [15], or through changes to the stretch load (via an increase in drop height within rebound orientated jumping tasks) [16]. Thus, reactive strength provides a measurement of an athlete's ability to produce force rapidly. Given sporting tasks are often constrained by time, assessment of these qualities can provide useful information for the purpose of exercise prescription and routine monitoring of athletes.

The reactive strength index (RSI) is a metric used to examine an individual's capacity to effectively utilise the SSC [17], and is traditionally measured during tasks indicative of fast SSC [17]. RSI is calculated via division of either jump height or flight time by the respective ground contact time and has shown moderate to strong levels of reliability (ICC: 0.57-0.99; CV: 2.98-14%) across a range of populations [18-23]. A drop jump has been the most common method of assessing RSI [17-19,21], and has since been explored in alternative tasks such as the depth jump [24], and repeated jump tests [23,25-27]. When aiming to maximise the resultant RSI score, the goal of the task (irrespective of the test) is to minimise ground contact time and maximise displacement of the jump (be it vertical or horizontal in nature) [17], which is synonymous with various physical and sports performance tasks such as sprint acceleration [28], and cutting steps to facilitate change of direction (COD) [29].

The associations between RSI and measures of physical and sports performance have been well documented in the literature. Previous studies have explored a variety of sports such as volleyball [30], rugby [31], soccer [11,32], hockey [33], sprinting [34], tennis [35], basketball [11,36], and competitive levels including collegiate [31], national [33], international [34], professional [37], semi-professional [38], and, novice/recreational [39]. Relationships of RSI have also been explored with a range of physical capacities, including strength [31,34], power (inclusive of jumping variations) [19,40,41], speed [34,42], and endurance performance [43,44]. The findings are not conclusive, and the strength of associations have been shown to vary. For example, Kipp, Kiely & Geiser [41] reported significant associations with RSI and vertical stiffness across numerous drop heights (30 cm: r = 0.54; 45 cm: r = 0.68; 60 cm: r = 0.75), whereas Healy, Kenny & Harrison [45] found comparable significant associations in males (30 cm: r = 0.78) but not females (30 cm: r = 0.56), with 95% CI values as low as 0.04. Such disparity also shines light on inconsistencies which are apparent for drop height within testing processes, which inevitably alters the task and thus the athletes strategy to complete the test optimally. Inconsistencies are also apparent for measures of strength. Cronin and Hansen [37] identified a negative association between RSI and a 3RM back squat (r = -0.18), in contrast to positive associations for 1RM and 3RM squat in other studies (r = 0.07 to 0.70) [11,38,46,47]. Inconsistencies for endurance performance [43,44] and both linear and COD speed [34,42] have also been shown, with a variety of drop heights evidenced throughout. Cumulatively, this suggests a synthesis of the available literature is warranted. More clearly understanding both testing strategies and the strength of associations between RSI and measures of physical capacity and sports performance can provide practitioners with useful information relating to the development of more targeted testing and monitoring strategies, and may also inform the programme design process, and thus warrants a deeper level of investigation.

Therefore, the aim of this review was to examine the associations between RSI measured during rebound jumping tasks and associations to physical and sporting performance tasks. Based on our findings, we also provide directions for future research.

2. METHODOLOGY

2.1 Study Design

This systematic review with meta-analysis was developed in accordance with the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) [48]. A review protocol was not pre-registered for this review.

2.2 Literature Search Methodology

A systematic literature search of four databases: PubMed, SPORTDiscus, Web of Science, and Ovid was conducted. Articles published between the inception of RSI in 1995 [17] and the search date of this review (22nd May 2020) were included. Figure 1 provides a schematic of the search methodology, and filtering strategies. The 3-level search strategy used grouping terms, truncation techniques, and phrase searching approaches, and combined all search terms with Boolean operators to: 1) avoid excessive quantities of unrelated articles; 2) encapsulate both the terminologies reactive strength index, and reactive strength ratio; 3) identify articles which utilised either a drop jump or equivalent rebound style jump; and 4) provide a clear link to physical and/or sporting performance. The full list of search criteria can be found in Table 1. Results were filtered to include studies published in peer-reviewed journals and written in English language. Additional searches were subsequently conducted via ResearchGate and Google Scholar if full-text articles were not fully available, including forward citation tracking using Google Scholar. Finally, reference lists of articles were manually checked for further studies that were deemed suitable and had not been identified using the search criteria stated above.

** Insert Figure 1 around here **

** Insert Table 1 around here **

2.3 Screening Strategy and Study Inclusion

All electronic search results were initially exported to ProQuest® RefWorks by the lead author (PJ) for bibliographic management. Articles were screened following a three-stage process: 1) duplicates of articles identified across numerous search databases were removed (PJ); 2) article title and abstracts were screened for suitability (PJ). Where a definitive decision could not be made at this stage, studies were taken forwards for a full study review; and 3) full articles were screened according to the inclusion and exclusion criteria by two reviewers independently (PJ, CB).

Inclusion criteria for the meta-analysis required studies to have correlated RSI to an independent measure of physical or sporting performance for at least one variable and provide rebound test instructions to minimise ground contact time, whilst maximising displacement in the jump. There were no restrictions concerning gender or sporting/athletic experience of participants. Studies were excluded due to one or more of the following reasons: 1) non peer-reviewed or original research, 2) published in a non-English language, 3) did not measure RSI as a function of jump height or flight time relative to contact time within a rebound jump, 4) included injured or youth participants or, 5) the full text was unavailable.

2.4 Data Extraction

To address the primary aims of this meta-analysis, data from each of the included articles were extracted by the lead author (PJ) and categorised into the following themes: 1) participant characteristics, 2) reactive strength index/ratio test used, and calculation method, 3) performance outcome measure(s) and, 4) association(s) to performance.

Data for both reactive strength index (utilising jump height and contact time) and ratio (flight time and contact time) were included based on the foundation that field based measurement tools utilise flight time to derive jump height, and therefore are both mathematically derived from the same information ($r = 0.97$, 95% Confidence Intervals (CI): 0.91-0.99) [49,50].

2.5 Methodological Quality and Risk of Bias Assessment

To appraise study methodological quality, a modified version of the Downs and Black Quality Index tool was used [51] in accordance with other studies [52-54]. For this review, 10 items in the checklist were deemed relevant (see Table 2), with questions associated to patient treatment, training interventions, and group randomisation processes removed as they were not applicable to the research question. Each item is scored as either a 1 (yes = "+"), or a 0 (no = "–" /unable to determine = "?"), with a total score out of 10. The articles were independently rated against the checklist criteria by two authors (PJ, CB), with any disparity discussed to finalise the rating outcome. A third author (AT) arbitrated disagreements. Interpretations have been provided for each question where applicable.

** Insert Table 2 around here **

2.6 Statistical Analysis

Separate Microsoft Excel (*Microsoft Excel, Microsoft Corporation, Version 2105*) sheets were generated for each of the outcome variables: (1) isometric strength, (2) isokinetic strength, (3) isotonic strength, (4) all strength measures pooled, (5) endurance performance (defined for the context of this review as any test measuring cardiorespiratory markers either directly or via use of proxy measures such as total distance covered during prolonged maximal or sub maximal exercise [55]), (6) sprint performance: acceleration (defined as any linear sprint distance/interval less than 30m [56], with data reported in seconds), (7) sprint performance: top speed and speed maintenance (defined as any linear sprint distance/interval between 30m-100m [56], with data reported in seconds), and (8) change of direction speed (defined as any closed skill test involving a pre-planned COD within a locomotive task [57]).

To account for the magnitude of the standard error associated to each of the included studies (as a result of different methodologies/measurement tools/athlete samples etc.), a random effects meta-analysis was conducted using jamovi (*jamovi,* Version 1.6.23.0), an open source statistical software package built on top of the R statistical language. This enabled for studies to be weighted relative to their standard error within the random effects model. Separate analyses were run for each of the outcome variables. Studies were required to have used the Pearson product-moment correlation coefficient (*r* value) to report associations and ensure eligibility for inclusion in the random effects meta-analysis model.

2.7 Study Effect Size Calculation

To account for the natural variation in skewness of the sampling distribution of Pearson's *r*, z-transformed *r* values (i.e. z_r values) were computed according to the formula:

$$z_r = 0.5 \text{ x} \ln\left(\frac{1+r}{1-r}\right)$$

where *r* is the reported Pearson's *r* value, and ln is the natural logarithm [58]. This enables for the calculation of symmetric CI's around z_r, based on knowledge of the variance of z_r:

$$V_z = \frac{1}{\mathrm{n}-3}$$

where n is the sample size, and also the standard error:

$$SE_z = \sqrt{V_z}$$

Symmetric 95% CI's around z_r can be calculated based on the following formula:

$$\left[z_r - z_{c/100} \text{ x } \frac{1}{\sqrt{\mathrm{N}-3}}, z_r + z_{c/100} \text{ x } \frac{1}{\sqrt{\mathrm{N}-3}}\right]$$

where $z_{c/100}$ is the critical z value (where 95% CI = $z_{0.95}$ = 1.96), and $1/\sqrt{N-3}$ being the SE_z. To back transform data from z_r to Pearson's *r* for reporting purposes, the following formula was used:

$$r = \frac{e(2 \text{ x } z_r) - 1}{e(2 \text{ x } z_r) + 1}$$

where *e* is the base of the natural logarithm, and z_r is the z-transformed effect size statistic [58].

Reporting of multiple effect sizes within a meta-analysis from the same cohort of participants violates the assumption of independence used in meta-analytic modelling. To address this, where studies reported multiple Pearson's *r* values that met the criteria for any of the outcome variables (for example 5m, 10m, and 20m sprint time all under the umbrella of sprint performance: acceleration), the following process was conducted: (1) Pearson's *r* data was transformed to z_r data, (2) an average within-sample effect size was calculated by averaging the z_r data, and (3) z_r data was back transformed to Pearson's *r* for reporting. This process was conducted for all identified cases, except where multiple values reported were a construct of the raw value (for example reporting of peak force and also peak force relative to body mass). In these circumstances, solely the raw value was utilised to minimise double counts of individual data points. Additionally, where outcome variables reported conflicting associations in favour of RSI positively impacting performance (for example endurance performance where Yo-Yo IRT score and running economy reflect a positive and negative association with RSI impacting performance, respectively), all negatively aligned data were positively transformed via use of the formula "=*-1" on Excel. This ensured that all data were matched regarding direction of alignment and enabled subsequent analysis within the random effects model. Findings are reported with associated 95% CI's and are interpreted as per the work of Cohen [59], with a Pearson's r value of 0.10, 0.30, and 0.50 identified as a small, moderate, and large effect, respectively.

Forest plots are displayed for each of the respective analyses, with information provided pertaining to the authors, and reference to the methods of analysis used in the subsequent brackets. Information on limb used (B = bilateral, U = unilateral), drop height, and outcome tasks associated to are provided for ease of comparison and visualisation purposes. Where multiple values were pooled to provide a single study effect size, this is noted as "Pooled".

2.8 Stability and Validity of Changes in Effect Sizes

To assess for the presence and degree of heterogeneity in the data, both the Q statistic and I^2 were used [60-62]. Statistical significance for Q was acknowledged at an alpha level of < 0.10 [60-62], and I^2 was interpreted as per the work of Higgins et al. [61], where an I^2 value 0-25% indicates trivial, 25-50% low, 50-75% moderate, and 75-100% high.

To assess for risk of small study bias (inclusive of publication bias), firstly funnel plots were created. This enabled for the visualisation of the spread of correlation coefficients, relative to their standard error. Qualitative analysis of funnel plots was only conducted where the number of studies within the analysis was equal to or exceeded 10 [63]. Egger's regression test [64] was conducted to quantify any asymmetries in the spread of data, and thus risk of small study bias. The Egger's regression test provides a quantitative analysis of the funnel plot by regression of the standardized effect estimates against their precision (inverse standard error), and measures asymmetry within the funnel plot by determining whether significant deviations from zero are apparent at the intercept. The occurrence of small study bias was considered present where $p < 0.05$, and in the event of this occurring, the required number of studies via the trim and fill method are presented [65].

3. RESULTS

3.1 Literature Search Results

A total of 1320 articles were identified (Figure 1), of which 892 duplicates were removed. A further 340 studies were excluded based on title and abstract screening. Full text screening was conducted on 88 articles, and 60 studies were removed at this stage due to not meeting the inclusion criteria. An additional 4 sources were identified via reference list checks and forward citation tracking. A total of 32 studies were identified for inclusion in this review and meta-analysis. A general description of the characteristics is provided in Table 4.

** Insert Figure 1 around here **

** Insert Table 4 around here **

3.2 Methodological Quality and Risk of Bias Assessment

Study methodological quality is shown in Table 3. There was no evidence of internal validity bias. We were unable to explicitly confirm external validity for 30/32 included studies as most failed to report the proportion of individuals recruited relative to the sample population. Scores ranged between 6/10 and 10/10 for study methodological quality and risk of bias. No studies were removed due to quality, and none reported conflicts of interest and/or funding sources which may impact the findings of the respective studies included in the meta-analysis.

** Insert Table 3 around here **

3.3 Meta-Analysis

The results of each meta-analysis are shown in Table 5. A range of studies reported metrics for strength (isometric: n = 5, isokinetic: n = 2, isotonic: n = 7), speed (acceleration: n = 16, top speed: n = 7), endurance performance (n = 3), and COD speed (n = 13). Forest plots for each physical performance measure are displayed in Figures 2-8.

** Insert Table 5 around here **

3.3.1 Strength

Isometric (r = 0.356 [95% CI's: 0.209, 0.504], Z = 4.74, p < 0.001) and isotonic strength (r = 0.365 [0.075, 0.654], Z = 2.47, p = 0.014) were significantly associated with RSI. Tests for heterogeneity were identified as trivial (I^2 = 0%, Q = 3.033, p = 0.695) and significant and moderate (I^2 = 66.02%, Q = 18.418, p = 0.005) respectively. There was no evidence of small study bias across the different strength modes (p > 0.05). Insufficient data was present to enable analysis of isokinetic strength data within its own independent analysis.

When all measures of strength were pooled, analyses indicated a significant association with RSI (r = 0.339 [0.209, 0.469], Z = 5.11, p < 0.001). Tests for heterogeneity were identified as low (I^2 = 27.74%, Q = 17.271, p = 0.14), and there was no evidence of small study bias (p = 0.283).

** Insert Figure 2 around here **

** Insert Figure 3 around here **

** Insert Figure 4 around here **

3.3.2 Endurance Performance

Endurance performance was significantly associated with RSI (r = 0.401 [0.173, 0.629], Z = 3.45, p < 0.001). Tests for heterogeneity were identified as trivial (I^2 = 0%, Q = 3.314, p = 0.346), and there was no evidence of small study bias (p = 0.074).

** Insert Figure 5 around here **

3.3.3 Speed

Acceleration (r = -0.426 [-0.562, -0.290], Z = -6.14, p < 0.001) and top speed (r = -0.326 [-0.502, -0.151], Z = -3.65, p < 0.001) were significantly associated with RSI. Tests for heterogeneity were identified as low (I^2 = 31.11%, Q = 22.992, p = 0.114) and trivial (I^2 = 0%, Q = 6.351, p = 0.499) respectively. There was evidence of small study bias for acceleration based on a trim and fill requirement of three studies (p = 0.01). Funnel plot for visual inspection is provided in Figure 9. There was no evidence of small study bias for top speed (p = 0.098).

** Insert Figure 6 around here **

** Insert Figure 7 around here **

** Insert Figure 9 around here **

3.3.4 Change of Direction Speed

COD speed was significantly associated with RSI (r = -0.565 [-0.726, -0.404], Z = -6.87, p < 0.001). Tests for heterogeneity were identified as significant and moderate (I^2 = 56.72%, Q = 31.00, p = 0.003), and there was evidence of small study bias based on a trim and fill requirement of five studies (p = 0.029). Funnel plot for visual inspection is provided in Figure 10.

** Insert Figure 8 around here **

** Insert Figure 10 around here **

4. DISCUSSION

The aim of this review was to examine the associations between RSI measured during rebound jumping tasks and physical and sports performance tasks. The overall unadjusted findings from this systematic review with meta-analysis demonstrate that significant and moderate associations are apparent between RSI and measures of strength (isometric: r = 0.356; isotonic: r = 0.365; pooled strength measures: r = 0.339), and endurance performance (r = 0.401). Significant moderate and negative associations were shown for measures of speed (acceleration: r = -0.426; top speed: r = -0.326), and large negative associations for COD speed (r = -0.565). Cumulatively, these findings indicate that greater RSI relates to improved performance in a range of physical capacities and sports performance tasks.

4.1 Strength

The findings from the meta-analysis suggest that measures of strength are significantly and positively associated with RSI, indicating that stronger individuals achieve larger RSI scores. These findings indicate that strength plays a role in modulating performance within rebound jumping tasks. However, the magnitude of these relationships were moderate [59], suggesting that a substantial portion of the variance in RSI performance may potentially be explained by other factors.

All studies apart from two reported a positive association between RSI and measures of strength [34a,37]. Healy et al. [34a] comprised a sample of national to international level sprinters, whereas Cronin and Hansen [37] used a sample of professional rugby-league players. Previous research has highlighted the importance of muscular strength and its role in athletic performance tasks [66-68], with suggestions of a back squat 1 repetition maximum of twice bodyweight being a potential threshold indicative of a greater performance in athletic tasks [66]. Cronin and Hansen [37] reported approximately 1.73 to 1.94 $kg.kg^{-1}$ body mass of relative strength within a 3RM back squat (calculated for illustration based on group average values), and Healy et al. [34a] reported 36.3 ± 6.2 $N.kg^{-1}$ within the IMTP relative to body mass (approximately 3.5-3.75x body mass, and calculated for illustration based on group average values). The beneficial effects of strength on athletic performance tasks have been widely noted in the literature [66-68], but the findings of Cronin and Hansen [37] and Healy et al. [34a] appear to contradict such evidence (r = -0.18 and -0.02, respectively). Jiménez-Reyes et al. [69] showed that as athlete training status increases, a decrease in the magnitude of correlations can be found in sporting performance tasks. This suggests that, whilst movement expression is built upon a foundation of physical capacity, training status has an important role in changing the reliance from maximal outputs in untrained populations towards mechanical effectiveness in elite populations [69,70], and may in part explain our findings.

Research by Alkjaer et al. [71] identified a significant increase in drop jump performance both in jump height achieved and the resultant RSI score following 4 weeks of intensive drop jump training, with muscle strength parameters unaffected. Thus, a more specific strength adaptation relative to the task may bring about a greater performance within rebound jumping tasks [72], highlighting the importance of training history and the nature of the sport competed in. Participants in the current review were from various sports and levels of competition, including: volleyball [30], rugby [31,33,37,38,46,47], weightlifting [11,31], soccer [11,33], hockey [33], running [31], powerlifting [31], sprinting [33,34], tennis [35], basketball [11], and skill levels; collegiate [30,31,46], national [33,33], international [33,34], professional [37,47], semi-professional [38], and, novice/recreational [11,31,35,39]. Few studies explicitly stated whether participants had prior experience with the drop jump, which would impact the skill level of the participants when completing the task due to inevitable increases in movement variability. Collectively, these discrepancies may have contributed to the observation of moderate associations. Further research is needed to more fully understand the role of strength in modulating changes in RSI.

4.2 Endurance Performance

Our findings suggest that associations between RSI and measures of endurance performance were positive and moderate. The positive correlation indicates that individuals with larger RSI scores achieve greater endurance performance, either through a reduced energy cost or greater total distance covered. All studies used running protocols, which have been shown to evoke successive eccentric-concentric actions throughout each ground contact [73,74]. Two of the three included studies used proxy measures of endurance performance, with both Jones [43] and Wilkinson [44] using intermittent shuttle based running tests until volitional fatigue. While the notion of specificity to sporting scenarios may hold true for the sample populations (Rugby League and Squash athletes), it is important to note that these studies did not measure any cardiorespiratory markers. Li et al. [75] acquired cardiorespiratory data for running economy at varying running speeds (measured as the average VO_2 [$mL \cdot kg^{-1} \cdot min^{-1}$] over the last minute of each running speed), and as such may provide greater insight. The strongest relationship was evident when exploring RSI relative to running economy [75], where testing methods are more heavily controlled compared to field based intermittent running protocols. This removes the repeated acceleration, deceleration, and COD experienced within intermittent running tests, which may present mechanical breakdown in technical factors throughout, as opposed to cardiorespiratory fatigue in controlled steady state motorised treadmill running. Li et al. [75] identified both moderate (r = -0.419) and large (r = -0.559 to -0.572) associations with running economy and RSI, indicating that individuals with larger RSI values were more efficient in a sustained running task. They also observed that as running speed increased, so too did the strength of relationship with RSI. These findings are perhaps best explained by an increased reliance on fast SSC mechanics throughout respective ground contacts, and less so a reflection of an increase in cardiorespiratory function [10,76]. Saunders et al. [77] showed a significant 4.1% increase in running economy at 18 $km.h^{-1}$ with no changes in any cardiorespiratory markers measured following 9 weeks of plyometric training. Similarly, Saunders et al. [77] also reported a 14% shift in the slope between VO_2 and running speed/power output following a 9 week plyometric training intervention, indicating an increased reliance on elastic mechanisms to facilitate propulsion, relative to muscle contractile properties, as a proportion of total work done. Thus, it can be suggested that improvements in running economy are connected to locomotor metabolism, the efficiency of elastic energy return and the SSC.

4.3 Speed

The present meta-analysis suggests that speed is significantly and moderately associated with RSI, and that individuals with larger RSI scores also achieve faster sprint times across both acceleration and top speed. However, evidence of small study bias was apparent for acceleration, thus caution should be applied when interpreting the findings, highlighting a requirement for further evidence.

The strength of association between measures of speed and RSI varied between studies (0.04 to -0.84 for acceleration; 0.04 to -0.63 for top speed). Some studies indicated larger associations with shorter distances, and others longer distances. Perhaps owing to the larger total number of studies, greater confidence was apparent in the summary estimate prediction from the random effects model for acceleration (r = -0.426 [-0.562, -0.290]), compared to top speed (r = -0.326 [-0.502, -0.151]). All studies reported a negative association except Healy et al. [34], in national to international level sprinters with at least 2 years of sprint and plyometric training experience. RSI has previously been shown to differentiate between faster and slower athletes in strength trained male field sport athletes [28]; however, Jiménez-Reyes et al. [69] identified a decrease in the magnitude of correlation found in sporting performance tasks as training status increased, suggesting a greater reliance on mechanical effectiveness as training status increases [69,70]. This is supported by the work of Morin, Edouard and

Samozino [70], who demonstrate that force application strategy is a determining factor in 100 m sprint performance, and not the total force applied. This supports the concept of dynamic correspondence in training transfer [78,79]. Thus, it could be suggested that horizontal RSI may provide stronger relationships when correlating to locomotive based tasks such as acceleration, given the fact that horizontal impulse accounts for the largest portion of variance in sprint acceleration ability (relative propulsive impulse = 57% variance, compared to relative braking impulse = 7% variance in sprint running velocity) [80]. Consideration however should be noted here relative to the direction of force application. In the context of a local frame (i.e., relative to the athlete), force application will be similar between vertical and horizontal tasks. However, when considering the global frame (i.e., fixed frame relative to the environment), alterations in body position to enable a horizontally orientated force vector will be required, which could result in a variety of strategies being adopted. As such, further research is needed to examine this concept from both a kinetic and kinematic perspective further.

4.4 Change of Direction Speed

The findings from the meta-analysis suggest that COD speed is significantly and negatively associated with RSI. This indicates that individuals with larger RSI scores also achieve faster COD speed times, with the strength of association interpreted as large. The importance of reactive strength in COD performance has previously been identified [57,81], enabling for the preservation of energy via utilisation of elastic energy storage and return [31,75,76,82]. Therefore, tests with a more acute COD speed angle may perhaps display a stronger association with RSI, given they enable individuals to capitalise on the SSC throughout the cutting step. Young et al. [83] examined RSI and performance in COD speed tests using 20° and 60° cuts with larger associations at the more acute (20°: r = -0.50 to -0.65) compared to 60° angle (r = -0.31 to -0.35). Dos'Santos et al. [29] suggest a greater reliance on preserving velocity for more acute cutting actions, compared to an increased reliance on braking in larger cutting angles with lower emphasis on fast SSC mechanics. Further research is warranted to explore the association between cutting angle and RSI to more clearly elucidate the strength of these relationships.

When interpreting the findings from the meta-analysis the significant and moderate heterogeneity should be considered. Sources of heterogeneity can likely be accounted for when considering the wide variation in COD speed test selection (505 COD test, T-test, custom COD tests, double cut COD tests, lateral shuffle COD tests, sport specific COD tests (basketball, fencing, squash), and single COD tests), rebound drop height (15 cm, 30 cm, 40 cm), and the fact that tests were either completed bilaterally, unilaterally, or both. COD speed performance is a construct of factors linking to technical, anthropometric, straight sprinting speed, and leg muscle qualities [57]. Where tests utilise greater straight line sprinting relative to changing direction as a proportion of total time taken, this may somewhat mask the individuals COD ability by simply being able to accelerate quickly. Tasks constraints should therefore be considered when interpreting relationships with RSI.

The evidence of small study bias must also be considered. Based on a trim and fill requirement of five studies when qualitatively viewing the funnel plot, it can be postulated that gaps are evident for studies displaying both a strong negative association, with high standard error, and moderate negative association, with low standard error. This may indicate that the association between RSI and COD speed is potentially larger than the summary estimate prediction from the random effects model utilised in this review. Further research is warranted to provide a more robust interpretation of the findings.

5. LIMITATIONS, PRACTICAL RECOMMENDATIONS, AND DIRECTIONS FOR FUTURE RESEARCH

Several factors should be considered when interpreting the findings of this review. We used a random-effects model within the analysis to factor in between study heterogeneity; however, this does not explain the sources of heterogeneity. There were a number of variations in the samples used (gender, training status, sport), test type (drop jump, horizontal drop jump, vertical rebound jump, vertical ankle rebound jump), drop heights (12, 15, 18, 20, 24, 30, 36, 40, 45, 48, 50, 60, 72, 75, 84 cm), and number of limbs used, which may facilitate alterations in jump strategy. Similarly, disparity in outcome measures (for example the range of COD speed tests), coupled with variations in equation used (jump height, jump distance, or flight time, and ground contact time) and units of measurement (JH: m, cm, mm; FT: s, ms; CT: s, ms) may all play a role in impacting the heterogeneity. However, the aim of this review was to establish an evidence base for the validity of any potential relationship, as opposed to identifying all potential correlates and reasons for deviations within the relationships [84]. Future research could explore possible moderators of the aggregate effect sizes identified within this meta-analysis. We also suggest a more uniform approach to the data collection process, owing to the large inconsistencies between studies. For example, a total of 15 different box heights were assessed across the 32 included studies. 26 studies reported RSI relative to jump displacement (either jump height or jump distance), with 5 reporting based on flight time of the jump. One study reported both methods of calculation, with differences in strength of association across the board apparent (for example COD speed: flight time method (r = -0.709), jump height method (r = -0.638)). We also propose consistency in units of measurement be utilised in an attempt to streamline cross comparison of studies, and pre-post testing time points.

Only 16/32 included studies reported completion of normality tests, which may have contributed to the prevalence of heterogeneity. There were concerns in both the utilisation of Pearson's r and the possibility of type 1 error within studies due to a lack of Bonferroni correction. To account for this, we only utilised the Pearson's r value from each study, thus negating the practical significance of p from each individual data source.

Specificity concerning the application of force has also been shown to be of key importance within tasks such as acceleration [70,80]. Future research could explore the notion of a horizontal measure of RSI to determine if stronger associations with linear speed are apparent. There is some evidence of this [85-88], however, different methods have been employed concerning the direction and height of the drop, and whether tasks were completed bilaterally [86,88] or unilaterally [85,87,88]. Further to this, all studies completed a vertical drop into the subsequent horizontal jump, which may detract from being an independent measure of horizontal reactive strength. Lastly, longitudinal tracking of RSI (and its construct parts) is required to elucidate changes in RSI and the makeup of this ratio following a training intervention. This is key to understanding how the individual components (i.e., jump height or flight time, and contact time) independently change in response to training, and how this impacts the subsequent relationship with physical and sporting performance outcomes.

6. CONCLUSION

The purpose of this systematic review and meta-analysis was to synthesise the available literature and examine associations between RSI and independent measures of physical and sports performance. We identified that relationships were primarily moderate, which is in contrast to previous suggestions. Large associations were present between RSI and COD speed. Factors affecting the strength of these relationships remains unclear, and there was evidence of heterogeneity and small study bias. Deviations in testing protocols and inconsistency in outcome measures used within each of the respective analyses may in part explain some of the variance. Future research may wish to consider using more standardised methods and explore the notion a horizontal index for RSI, given the relative importance of task specificity.

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Table 1. Schematic to represent 3-level search strategy.

Operator		Search Terms
	#1	"reactive strength"
AND	**#2**	(drop OR rebound OR repeat*) AND (jump* OR hop*)
AND	**#3**	performance OR sport OR strength OR force OR power OR jump* OR speed OR sprint* OR accelerati* OR (chang* AND direction) OR cut* OR run* OR endurance OR aerobic OR "lactate threshold" OR "running economy" OR VO_2* OR injury

Table 2. Questions from the modified Downs & Black [51] checklist used to evaluate methodological quality of the included articles.

Question No.	Question
	Reporting
1	Is the hypothesis/aim/objective of the study clearly described?
2	Are the main outcomes to be measured clearly described in the introduction or methods section?
	**Information outlined in introduction/methodology for both RSI and variables used for associative analysis pertaining to test(s) used, calculation method, and units of measurement.*
3	Are the characteristics of the subjects included in the study clearly described?
	** Source defined, with characteristics included.*
4	Are the main findings of the study clearly described?
5	Does the study provide estimates of the random variability in the data for the main outcomes?
	** One of: Mean ± SD[1], standard error[1], confidence intervals[1], or interquartile range[2] outlined for both RSI and variables used for associative analysis.*
6	Have actual probability values been reported (e.g., 0.035 rather than < 0.05) for the main outcomes except where the probability value is < 0.001?
	** Exact correlation (r) and significance (p) values provided, specific to the associative analysis.*
	External Validity
7	Were the subjects asked to participate in the study representative of the entire population from which they were recruited?
	** Proportion of subjects asked to participate, relative to the sample population, explicitly stated. Unless evident, then answer "unable to determine".*
	Internal Validity Bias
8	If any of the results of the study were based on “data dredging,” was this made clear?
	** If no signs of retrospective/unplanned data analysis, then answer "yes".*
9	Were the statistical tests used to assess the main outcomes appropriate?
10	Were the main outcome measures accurate (valid and reliable)?

Notes: [1] = normally distributed data, [2] = non normally distributed data

Table 3. Results of study methodological quality for included articles.

Reference	Downs & Black Checklist Item Number										Total Score /10
	Reporting						External Validity	Internal Validity Bias			
	1	2	3	4	5	6	7	8	9	10	
Barnes et al. [30]	+	+	+	+	+	-	?	+	+	+	**8**
Barr & Nolte. [89]	+	+	+	+	+	-	?	+	+	+	**8**
Barr & Nolte. [46]	+	+	+	+	+	-	?	+	+	+	**8**
Beattie et al. [31]	+	+	+	+	-	-	?	+	+	+	**7**
Birchmeier et al. [90]	+	+	+	+	+	-	?	+	+	+	**8**
Carr, McMahon & Comfort. [91]	+	-	+	+	+	-	?	+	+	+	**7**
Cronin & Hansen. [37]	+	+	+	+	-	-	?	+	+	+	**7**
Cunningham et al. [47]	+	-	+	+	-	-	?	+	+	+	**6**
Delaney et al. [92]	+	+	+	+	+	-	?	+	+	+	**8**
Douglas et al. [33]	+	+	+	+	+	-	?	+	+	+	**8**
Furlong, Harrison & Jensen. [38]	+	+	+	+	+	-	?	+	+	+	**8**
Healy et al. [34]	+	+	+	+	+	-	?	+	+	+	**8**
Holm et al. [87]	+	+	+	+	+	-	?	+	+	+	**8**
Jones et al. [43]	+	-	+	+	+	+	+	+	+	+	**9**
Li et al. [75]	+	+	+	+	+	+	?	+	+	+	**9**
Lockie et al. [93]	+	+	+	+	+	+	?	+	+	+	**9**
Loturco et al. [42]	+	+	+	+	+	-	?	+	+	+	**8**
Maloney et al. [94]	+	+	+	+	+	+	?	+	+	+	**9**
McCormick et al. [11]	+	+	+	+	+	+	?	+	+	+	**9**
McCurdy et al. [88]	+	+	+	+	+	-	?	+	+	+	**8**
Nagahara et al. [95]	+	+	+	+	+	-	?	+	+	+	**8**
Northeast et al. [96]	+	-	+	+	+	-	?	+	+	+	**7**
Pehar et al. [97]	+	-	+	+	+	-	?	+	+	+	**7**
Salonikidis & Zafeiridis. [35]	+	+	+	+	+	-	?	+	+	+	**8**
Schuster & Jones. [85]	+	+	+	+	+	-	?	+	+	+	**8**
Smirniotou et al. [98]	+	+	+	+	+	-	?	+	+	+	**8**
Tsolakis, Kostaki & Vagenas. [99]	+	+	+	+	+	-	?	+	+	+	**8**
Turner et al. [100]	+	+	+	+	+	-	?	+	+	+	**8**
Wilkinson et al. [44]	+	+	+	+	+	+	+	+	+	+	**10**
Young, James & Montgomery. [83]	+	+	+	+	+	-	?	+	+	+	**8**
Young, Miller & Talpey. [101]	+	+	+	+	+	+	?	+	+	+	**9**
Young, Wilson & Byrne. [39]	+	+	+	+	+	-	?	+	+	+	**8**

Notes: + = yes, – = no, ? = unable to determine

Table 4. Study characteristics for the studies included within this review.

Reference	Participants Characteristics					RSI			Performance Outcome Measure(s)	Associations to Performance
	n	Age (years)	Height (cm / m)	Body Mass (kg)	Training Status	Test Utilised	Calculation Method	Value		
Barnes et al. [30]	n = 29 (29 Females)	DI: 20.3 ± 1.5 DII: 19.6 ± 1.4 DIII: 20.0 ± 1.3	DI: 177.9 ± 6.3 cm DII: 174.3 ± 7.7 cm DIII: 171.0 ± 8.0 cm	DI: 73.3 ± 7.7 DII: 71.5 ± 9.8 DIII 69.8 ± 6.9	Collegiate volleyball players DI (n = 9), DII (n = 11), DIII (n = 9)	DJ ** 30cm vertical drop **	JH (cm) / CT (s)	80.0 ± 15.4	ISOS PF (N)	$r = 0.401$, $p > 0.05$
Barr & Nolte. [89]	n = 15 (15 Females)	ND	1.71 ± 0.5 m	71.65 ± 9.99	Strength trained university rugby players (strength training background: 2.67 ± 1.11 years)	DJ ** 12cm vertical drop **	JH (cm) / CT (s)	125 ± 24	0-10m ST (s) 10-30m ST (s) 30-60m ST (s)	$r = -0.06$, $p > 0.05$ $r = -0.21$, $p > 0.05$ $r = -0.02$, $p > 0.05$
						DJ ** 24cm vertical drop **		132 ± 23	0-10m ST (s) 10-30m ST (s) 30-60m ST (s)	$r = 0.13$, $p > 0.05$ $r = -0.09$, $p > 0.05$ $r = 0.18$, $p > 0.05$
						DJ ** 36cm vertical drop **		129 ± 22	0-10m ST (s) 10-30m ST (s) 30-60m ST (s)	$r = -0.01$, $p > 0.05$ $r = -0.27$, $p > 0.05$ $r = 0.01$, $p > 0.05$
						DJ ** 48cm vertical drop **		127 ± 26	0-10m ST (s) 10-30m ST (s) 30-60m ST (s)	$r = -0.20$, $p > 0.05$ $r = -0.51$, $p > 0.05$ $r = -0.33$, $p > 0.05$
						DJ ** 60cm vertical drop **		112 ± 23	0-10m ST (s) 10-30m ST (s) 30-60m ST (s)	$r = -0.14$, $p > 0.05$ $r = -0.33$, $p > 0.05$ $r = -0.15$, $p > 0.05$
						DJ ** 72cm vertical drop **		110 ± 20	0-10m ST (s) 10-30m ST (s) 30-60m ST (s)	$r = -0.30$, $p > 0.05$ $r = -0.56$, $p < 0.05$ $r = -0.42$, $p > 0.05$
						DJ ** 84cm vertical drop **		97 ± 25	0-10m ST (s) 10-30m ST (s) 30-60m ST (s)	$r = -0.25$, $p > 0.05$ $r = -0.57$, $p < 0.05$ $r = -0.42$, $p > 0.05$
Barr & Nolte. [46]	n = 15 (15 Females)	20.3 ± 0.5	1.71 ± 0.5 m	71.6 ± 9.9	Strength trained university rugby players (strength training background: 2.7 ± 1.1 years)	DJ ** 24cm vertical drop **	JH (cm) / CT (s)	132 ± 26	1RM Front Squat Relative to BM (kg)	$r = 0.15$, (95% CI: –0.31, 0.56)
						DJ ** 36cm vertical drop **		129 ± 20	1RM Front Squat Relative to BM (kg)	$r = 0.44$ (95% CI: 0.0, 0.74)
						DJ ** 48cm vertical drop **		127 ± 25	1RM Front Squat Relative to BM (kg)	$r = 0.6$ (95% CI: 0.21, 0.82)
						DJ ** 60cm vertical drop **		114 ± 17	1RM Front Squat Relative to BM (kg)	$r = 0.33$ (95% CI: –0.13, 0.67)
						DJ ** 72cm vertical drop **		110 ± 17	1RM Front Squat Relative to BM (kg)	$r = 0.7$ (95% CI: 0.37, 0.87)
						DJ ** 84cm vertical drop **		97 ± 24	1RM Front Squat Relative to BM (kg)	$r = 0.47$ (95% CI: 0.04, 0.76)

Beattie et al. [31]	n = 45	23.70 ± 4.00	1.80 ± 0.08 m	87.50 ± 16.10	Collegiate athletes across various sports Rugby union (n = 20) Weightlifting (n = 8) Distance running (n = 8) Powerlifting (n = 4) Recreational (n = 5)	DJ ** 30cm vertical drop **	JH (m) / CT (s)	ND	IMTP PF (N) IMTP PF Relative to BM (N/kg) IMTP PF Allometrically Scaled ($N/kg^{0.67}$)	*r* = 0.302, *p* < 0.05 *r* = 0.229, *p* > 0.05 *r* = 0.289, *p* > 0.05
						DJ ** 40cm vertical drop **		ND	IMTP PF (N) IMTP PF Relative to BM (N/kg) IMTP PF Allometrically Scaled ($N/kg^{0.67}$)	*r* = 0.286, *p* = 0.056 *r* = 0.304, *p* < 0.05 *r* = 0.327, *p* < 0.05
						DJ ** 50cm vertical drop **		ND	IMTP PF (N) IMTP PF Relative to BM (N/kg) IMTP PF Allometrically Scaled ($N/kg^{0.67}$)	*r* = 0.327, *p* < 0.01 *r* = 0.360, *p* < 0.05 *r* = 0.382, *p* < 0.01
						DJ ** 60cm vertical drop **		ND	IMTP PF (N) IMTP PF Relative to BM (N/kg) IMTP PF Allometrically Scaled ($N/kg^{0.67}$)	*r* = 0.349, *p* < 0.05 *r* = 0.425, *p* < 0.01 *r* = 0.431, *p* < 0.01
Birchmeier et al. [90]	n = 52 (35 Females, 17 Males)	22.94 ± 5.0	173.1 ± 9.9 cm	73.8 ± 11.7	History of unilateral ACL reconstruction (Time since surgery = 37.6 ± 23.7 months)	SL DJ ** 30cm vertical drop ** ** ACLR limb used **	JH (m) / CT (s)	0.2 ± 0.1	MVIC knee extension RTD ($Nm.s^{-1}$) MVIC knee extension RTD 100ms ($Nm.s^{-1}$) MVIC knee extension RTD 200ms ($Nm.s^{-1}$) MVIC knee extension Peak torque (Nm)	*r* = 0.071, *p* > 0.05 *r* = 0.291, *p* = 0.037 *r* = 0.473, *p* < 0.01 *r* = 0.609, *p* < 0.05
Carr, McMahon & Comfort. [91]	n = 16 (16 Males)	23.8 ± 3.7	185.34 ± 6.9 cm	85.4 ± 9.37	First-class county cricketers (5.1 ± 2.3 years competing at this level)	DJ ** 30cm vertical drop **	JH / CT	1.78 ± 0.35	20m ST (s)	*r* = –0.495, *p* > 0.05
Cronin & Hansen. [37]	n = 26 (26 Males)	23.2 ± 3.3	183.1 ± 5.9 cm	97.8 ± 11.8	Professional rugby league players, under contract with the New Zealand Warriors	DJ ** 40cm vertical drop **	JH (cm) / CT (s)	ND	5m ST (s) 10m ST (s) 30m ST (s) Squat 3RM (kg) Quadriceps peak torque 60 $deg.s^{-1}$ ($N.m^{-1}$) Hamstrings peak torque 60 $deg{\cdot}s^{-1}$ ($N.m^{-1}$) Quadriceps peak torque 300 $deg.s^{-1}$ ($N.m^{-1}$) Hamstrings peak torque 300 $deg{\cdot}s^{-1}$ (N·m-1)	*r* = –0.35, *p* > 0.05 *r* = –0.38, *p* > 0.05 *r* = –0.34, *p* > 0.05 *r* = –0.18, *p* > 0.05 *r* = –0.05, *p* > 0.05 *r* = –0.07, *p* > 0.05 *r* = –0.27, *p* > 0.05 *r* = –0.29, *p* > 0.05
Cunningham et al. [47]	n = 20 (20 Males)	26.5 ± 4.6	1.8 ± 0.1 m	105.5 ± 11.9	Professional rugby players (Structured weight training > 2years)	DJ ** 40cm vertical drop **	FT / CT (s)	ND	1RM Squat Relative to BM (kg/kg) 10m ST (s) Flying (20m approach) 10m ST (s)	*r* = 0.52, *p* < 0.05 *r* = –0.60, *p* < 0.01 *r* = –0.62, *p* < 0.01
Delaney et al. [92]	n = 31 (31 Males)	24.3 ± 4.4	1.83 ± 0.06 m	98.1 ± 9.8	Full-time professional rugby league players from the same National Rugby League club Forwards (n = 17), Backs (n = 14)	DJ ** 30cm vertical drop **	JH (m) / CT (s)	1.04 ± 0.23	505 CODs Dominant Limb (s) 505 CODs Non-Dominant Limb (s)	*r* = –0.44, *p* ≤ 0.05 *r* = –0.45, *p* ≤ 0.05
Douglas et al. [33]	n = 24 (13 Males, 11 Females)	Team sport athletes: 23 ± 3 Trained track & field sprinters: 23 ± 5	Team sport athletes: 172 ± 4 cm Trained track & field sprinters: 177 ± 9 cm	Team sport athletes: 72.8 ± 8.0 Trained track & field sprinters: 73.6 ± 10.2	Trained team sport athletes (n = 13) & highly trained track & field sprinters (n = 11; IAAF Points: 1039 ± 59)	DJ ** 50cm vertical drop **	FT (s) / CT (s)	Team sport: 2.71 ± 0.35 Trained sprinters: 2.98 ± 0.42	Isoinertial eccentric force ($N.kg^{-1}$)	*r* = 0.60 (90% CI: 0.31, 0.79)
Furlong, Harrison & Jensen. [38]	n = 21 (21 Males)	19.5 ± 2.1	1.84 ± 0.06 m	94.0 ± 11.5	Sub elite semi-professional adult Rugby Union players (40 yd sprint time = 5.382 ± 0.352 s)	DJ ** 30cm vertical drop **	JH (m) / CT (ms)	0.894 ± 0.203	1RM BS Relative to BM (kg/kg) 30m ST (s)	*r* = 0.074, *p* > 0.01 *r* = –0.685, *p* < 0.01

Healy et al. [34]	n = 28 (14 Males, 14 Females)	Males: 22 ± 2	Males: 1.82 ± 0.07 m	Males: 73.1 ± 6.8	National (7 Males, 6 Females) & international (7 Males, 8 Females) level sprinters (>2 years sprint and plyometric training experience)	DJ ** 30cm vertical drop **	JH (m) / CT (s)	Males: 2.06 ± 0.43	0-10m ST (s) 10-20m ST (s) 20-30m ST (s) 30-40m ST (s) 40m ST (s) IMTP PF (N) IMTP Relative PF ($N.kg^{-1}$)	*r* = –0.03, *p* > 0.05 *r* = 0.01, *p* > 0.05 *r* = 0.14, *p* > 0.05 *r* = –0.02, *p* > 0.05 *r* = 0.02, *p* > 0.05 *r* = –0.02, *p* > 0.05 *r* = 0.34, *p* > 0.05
		Females: 22 ± 4	Females: 1.72 ± 0.07 m	Females: 64.4 ± 4.6		DJ ** 30cm vertical drop **		Females: 1.65 ± 0.35	0-10m ST (s) 10-20m ST (s) 20-30m ST (s) 30-40m ST (s) 40m ST (s) IMTP PF (N) IMTP Relative PF ($N.kg^{-1}$)	*r* = –0.04, *p* > 0.05 *r* = 0.21, *p* > 0.05 *r* = 0.02, *p* > 0.05 *r* = 0.04, *p* > 0.05 *r* = 0.04, *p* > 0.05 *r* = 0.12, *p* > 0.05 *r* = 0.31, *p* > 0.05
Holm et al. [87]	n = 20 (20 Males)	22 ± 3	180 ± 7 cm	80 ± 9	Regional level team sport athletes for >3years (touch football, rugby, basketball), with general resistance training experience	SL Horizontal DJ ** 20cm vertical drop, into jump for max distance. Average of best L & R trials used in analysis **	JD (cm) / CT (s)	430 ± 79	0-5m ST (s) 0-10m ST (s) 0-25m ST (s) 5-10m ST (s) 10-25m ST (s)	*r* = –0.14, *p* > 0.05 *r* = –0.15, *p* > 0.05 *r* = –0.12, *p* > 0.05 *r* = –0.07, *p* > 0.05 *r* = –0.09, *p* > 0.05
Jones et al. [43]	n = 27 (27 Females)	Backs: 23.5 ± 4.1 Forwards: 26.3 ± 6.4	Backs: 163.1 ± 4.0 cm Forwards: 167.4 ± 6.8 cm	Backs: 66.0 ± 7.3 Forwards: 80.7 ± 14.3	Elite female rugby league players, talent identified before the 2017 Rugby League World Cup Backs (n = 15), Forwards (n = 12)	DJ ** 30cm vertical drop **	JH (m) / CT	Backs: 0.87 ± 0.31 Forwards: 0.58 ± 0.13	5m ST (s) 10m ST (s) 20m ST (s) 30m ST (s) 40m ST (s) 505 agility test R (s) 505 agility test L (s) Yo-Yo IRT-1 (m)	*r* = –0.331, *p* = 0.091 *r* = –0.348, *p* = 0.075 *r* = –0.347, *p* = 0.076 *r* = –0.427, *p* = 0.026 *r* = –0.373, *p* = 0.055 *r* = –0.459, *p* = 0.016 *r* = –0.447, *p* = 0.020 *r* = 0.436, *p* = 0.023
Li et al. [75]	n = 28 (28 Males)	20.7 ± 1.2	177.3 ± 4.94 cm	60.81 ± 5.24	Collegiate long distance runners (5000m, 10000m, marathon), with >4years long distance training experience	DJ ** 40cm vertical drop **	JH (cm) / CT (s)	61.72 ± 11.51	RE @ 12 $km.h^{-1}$ RE @ 14 $km.h^{-1}$ RE @ 16 $km.h^{-1}$	*r* = –0.419, *p* = 0.027 *r* = –0.559, *p* = 0.002 *r* = –0.572, *p* = 0.001
Lockie et al. [93]	n = 16 (16 Males)	23.31 ± 5.34	1.78 ± 0.07 m	80.6 ± 9.9	Recreationally active field sport athletes (soccer, rugby league, rugby union, Australian football, touch, Oztag)	DJ ** 40cm vertical drop **	FT (s) / CT (s)	1.771 ± 0.400	0-10m ST (s) 0-20m ST (s) 0-40m ST (s) T-Test COD (s) COD & acceleration test (s)	*r* = –0.690, *p* = 0.003 *r* = –0.577, *p* = 0.019 *r* = –0.558, *p* = 0.025 *r* = –0.546, *p* = 0.029 *r* = –0.709, *p* = 0.002
							JH (m) / CT (s)	0.971 ± 0.326	0-10m ST (s) 0-20m ST (s) 0-40m ST (s) T-Test COD (s) COD & acceleration test (s)	*r* = –0.680, *p* = 0.004 *r* = –0.632, *p* = 0.009 *r* = –0.536, *p* = 0.032 *r* = –0.506, *p* = 0.045 *r* = –0.638, *p* = 0.008
Loturco et al. [42]	n = 19 (12 Males, 7 Females)	Males: 22.3 ± 2.4 Females: 23.8 ± 4.2	Males: 176.5 ± 5.6 Females: 167.4 ± 5.8	Males: 75.5 ± 8.3 Females: 56.9 ± 5.4	Elite power track & field athletes (4 long jumpers, 15 sprinters)	DJ ** 45cm vertical drop **	JH (cm) / CT (ms)	Males: 1.08 ± 0.33 Females: 1.17 ± 0.31	10m ST (s) 20m ST (s) 40m ST (s) 60m ST (s)	*r* = –0.31, *p* > 0.05 *r* = –0.18, *p* > 0.05 *r* = –0.14, *p* > 0.05 *r* = –0.06, *p* > 0.05
						DJ ** 75cm vertical drop **		Males: 1.04 ± 0.27 Females: 1.03 ± 0.26	10m ST (s) 20m ST (s) 40m ST (s) 60m ST (s)	*r* = –0.43, *p* > 0.05 *r* = –0.34, *p* > 0.05 *r* = –0.33, *p* > 0.05 *r* = –0.24, *p* > 0.05

Maloney et al. [94]	n = 18 (18 Males)	22 ± 4	1.80 ± 0.08 m	81.7 ± 14.9	Recreationally active individuals (undertaking ≥ 2.5 h of physical activity per week)	SL DJ ** 18cm vertical drop ** ** Average of L&R Limbs used for RSI value **	FT (s) / CT (s)	Faster group: 1.02 ± 0.22 Slower group: 1.00 ± 0.10	Double cut COD speed (s)	$r = -0.337$, $p = 0.172$
McCormick et al. [11]	n = 23 (23 Males)	21.87 ± 2.62	1.77 ± 0.085 m	75.69 ± 15.25	Active individuals (weightlifting, soccer, basketball) as part of University programme	DJ ** 30cm vertical drop **	JH (mm) / CT (ms)	2.05 ± 0.45	3RM Squat (kg) 5s Lateral shuffle test L (n) 5s Lateral shuffle test R (n)	$r = 0.083$, $p = 0.707$ $r = 0.012$, $p = 0.958$ $r = -0.001$, $p = 0.997$
McCurdy et al. [88]	n = 15 (15 Females)	20.19 ± 0.91	165 ± 2.44 cm	61.65 ± 7.7	DI female soccer players from the National Collegiate Athletic Association (NCAA)	SL DJ ** 20cm vertical drop ** ** Average of L&R Limbs used for RSI value **	JH (m) / CT (s)	L&R Pooled: 1.16 ± 0.50	10m ST (s) 25m ST (s)	$r = 0.16$, $p > 0.05$ $r = -0.02$, $p > 0.05$
						SL Horizontal DJ ** 20cm vertical drop ** ** Average of L&R Limbs used for RSI value **	JD (m) / CT (s)	L&R Pooled: 4.11 ± 1.32	10m ST (s) 25m ST (s)	$r = 0.08$, $p > 0.05$ $r = -0.49$, $p > 0.05$
Nagahara et al. [95]	n = 19 (19 Males)	20.1 ± 1.2	1.75 ± 0.04 m	66.1 ± 4.0	Male sprinters (100m PB: 11.19 ± 0.34 s, ranging from 10.72 - 11.79 s)	Vertical Rebound Jumps ** 6 jump method, utilising largest RSI score from the 5 rebound jumps **	JH (m) / CT (s)	2.634 ± 0.373	60m ST (s)	$r = -0.07$, $p > 0.05$
						Vertical Ankle Rebound Jumps ** 6 jump method, utilising largest RSI score from the 5 ankle rebound jumps **		1.132 ± 0.268	60m ST (s)	$r = -0.49$, $p < 0.05$
Northeast et al. [96]	n = 26	25 ± 4	1.79 ± 0.08 m	76.3 ± 8.6	Professional soccer players from an English Premier League senior team	DJ ** 40cm vertical drop **	FT / CT (ms)	2.50 ± 0.47	5m ST (s) 10m ST (s) 20m ST (s) Preplanned Multidirectional sprinting L (s) Preplanned Multidirectional sprinting R (s)	$r = -0.121$, $p > 0.05$ $r = -0.165$, $p > 0.05$ $r = -0.167$, $p > 0.05$ $r = -0.145$, $p > 0.05$ $r = -0.150$, $p > 0.05$
						SL DJ ** 20cm vertical drop **		Left Leg: 1.35 ± 0.23	5m ST (s) 10m ST (s) 20m ST (s) Preplanned Multidirectional sprinting L (s) Preplanned Multidirectional sprinting R (s)	$r = -0.227$, $p > 0.05$ $r = -0.320$, $p > 0.05$ $r = -0.256$, $p > 0.05$ $r = -0.243$, $p > 0.05$ $r = -0.274$, $p > 0.05$
								Right Leg: 1.38 ± 0.25	5m ST (s) 10m ST (s) 20m ST (s) Preplanned Multidirectional sprinting L (s) Preplanned Multidirectional sprinting R (s)	$r = -0.239$, $p > 0.05$ $r = -0.336$, $p > 0.05$ $r = -0.309$, $p > 0.05$ $r = -0.201$, $p > 0.05$ $r = -0.355$, $p > 0.05$
Pehar et al. [97]	n = 88 (88 Males)	21.12 ± 3.47	194.62 ± 8.09 cm	89.13 ± 10.81	Basketball players involved in the highest national competitive rank in Bosnia & Herzegovina	DJ ** 40cm vertical drop **	JH / CT	1.58 ± 0.30	Basketball specific COD speed (s)	$r = -0.64$, $p < 0.05$

Salonikidis & Zafeiridis. [35]	n = 64	21.1 ± 1.3	1.74 ± 0.09	71.7 ± 13.1	Novice tennis players (2-3 years tennis experience) competing at beginner's level, with previous team sport experience	DJ ** 20cm vertical drop **	JH (cm) / CT (s)	125.3 ± 45.2	4m forward sprint speed trained limb (s) 4m forward sprint speed untrained limb (s) 12m forward sprint speed trained limb (s) 12m forward sprint speed untrained limb (s) 12m forward sprint with turn speed trained limb (s) 12m forward sprint with turn speed untrained limb (s) Seated Isometric bilateral PF (N) Seated Isometric unilateral PF trained limb (N) Seated Isometric unilateral PF untrained limb (N)	r = –0.64, p < 0.05 r = –0.67, p < 0.05 r = –0.66, p < 0.05 r = –0.61, p < 0.05 r = –0.72, p < 0.05 r = –0.75, p < 0.05 r = 0.40, p < 0.05 r = 0.43, p < 0.05 r = 0.36, p > 0.05
						SL DJ ** 20cm vertical drop **		Trained leg: 50.1 ± 19.6	4m forward sprint speed trained limb (s) 12m forward sprint speed trained limb (s) 12m forward sprint with turn speed trained limb (s) Seated Isometric bilateral PF (N) Seated Isometric unilateral PF trained limb (N)	r = –0.65, p < 0.05 r = –0.65, p < 0.05 r = –0.70, p < 0.05 r = 0.43, p < 0.05 r = 0.47, p < 0.05
								Untrained leg: 52.0 ± 18.4	4m forward sprint speed untrained limb (s) 12m forward sprint speed untrained limb (s) 12m forward sprint with turn speed untrained limb (s) Seated Isometric bilateral PF (N) Seated Isometric unilateral PF untrained limb (N)	r = –0.63, p < 0.05 r = –0.57, p < 0.05 r = –0.90, p < 0.05 r = 0.45, p < 0.05 r = 0.45, p > 0.05
Schuster & Jones. [85]	n = 19 (19 Males)	22.5 ± 3.2	181.1 ± 6.7 cm	80.3 ± 9.6	Collegiate team sport (Soccer and Rugby) athletes, with >2yrs resistance training experience	SL DJ ** 20cm vertical drop ** ** Average of L&R Limbs used for RSI value **	JH (m) / CT (s)	0.99 ± 0.06	5m ST (s) 10m ST (s) 15m ST (s) 20m ST (s) 5-10m ST (s) 10-15m ST (s) 15-20m ST (s)	r_s = –0.15, p > 0.05 r = –0.14, p > 0.05 r_s = –0.22, p > 0.05 r = –0.22, p > 0.05 r = –0.26, p > 0.05 r = –0.246, p > 0.05 r = –0.23, p > 0.05
						SL Horizontal DJ ** 20cm vertical drop, into jump for max distance ** ** Average of L&R Limbs used for RSI value **	JD (m) / CT (s)	4.42 ± 0.35	5m ST (s) 10m ST (s) 15m ST (s) 20m ST (s) 5-10m ST (s) 10-15m ST (s) 15-20m ST (s)	r_s = –0.06, p > 0.05 r_s = –0.10, p > 0.05 r_s = –0.06, p > 0.05 r_s = –0.05, p > 0.05 r_s = –0.06, p > 0.05 r_s = –0.11, p > 0.05 r_s = –0.11, p > 0.05
Smirniotou et al. [98]	n = 25 (25 Males)	18.73 ± 1.79	176.0 ± 5.1 cm	70.5 ± 4.3	Young male sprinters competing at regional level (100m PB: 11.71 ± 0.53 s)	DJ ** 40cm vertical drop **	JH (cm) / CT (s)	215.3 ± 36.9	10m ST (s) 30m ST (s) 60m ST (s) 100m ST (s)	r = –0.488, p < 0.05 r = –0.511, p < 0.01 r = –0.544, p < 0.01 r = –0.566, p < 0.01
Tsolakis, Kostaki & Vagenas. [99]	n = 28	20.0 ± 3.32	176.3 ± 7.7 cm	66.5 ± 9.64	Elite fencers from the Greek National Team (ranging from Olympic Games experience, Junior World Championships & International competitions)	DJ ** 40cm vertical drop **	JH (cm) / CT (s)	1.4 ± 0.54	Fencing specific test: 5m Shuttle test (s) Fencing specific test: 5m Shuttle test relative to BM ($s.kg^{-1}$)	r = –0.44, (95% CI: –0.70, –0.08) r = –0.56, (95% CI: –0.77, –0.24)
Turner et al. [100]	n = 36 (36 Males)	18.9 ± 3.2	174.35 ± 10.42 cm	70.67 ± 7.35	Elite senior & junior fencers (8.5 ± 4.2 yrs fencing experience)	DJ ** 30cm vertical drop **	FT (ms) / CT (ms)	1.65 ± 0.44	Fencing specific test: 4-2-2-4 m COD speed (s)	r = –0.56, p < 0.01
Wilkinson et al. [44]	n = 31 (20 Males, 11 Females)	Males: 26 ± 2 22 ± 1 20 ± 1 Females: 25 ± 2 21 ± 1 20 ± 1	ND	Males: 79.5 ± 6 69.9 ± 2.8 69.5 ± 6.8 Females: 62.5 ± 3.1 58.4 ± 1.7 66.2 ± 9.1	England Squash performance program athletes, world ranked from 3 to 364 Full time senior squad players (n = 12) Full time transition squad players (n = 7) Talented athlete scholarship scheme (n = 12)	DJ ** 30cm vertical drop **	JH (cm) / CT (s)	Males: 291 ± 45 294 ± 51 235 ± 54	Squash specific multiple sprint ability (s) Squash specific CODs (s) Estimated VO_2max ($ml.kg^{-1}.min^{-1}$)	r = -0.69, p < 0.01 r = –0.53, p = 0.02 r = 0.29, p = 0.29
								Females: 250 ± 31 252 ± 56 186 ± 21	Squash specific multiple sprint ability (s) Squash specific CODs (s) Estimated VO_2max ($ml.kg^{-1}.min^{-1}$)	r = –0.10, p = 0.78 r = –0.40, p = 0.22 r = –0.13, p = 0.70

Young, James & Montgomery. [83]	n = 15 (15 Males)	18 - 28	1.75 ± 0.08 m	74.6 ± 12.6	Competitively involved in sport requiring CODs (comprising of soccer, basketball, Australian football, tennis)	DJ ** 30cm vertical drop **	JH (cm) / CT (s)	195 ± 46	8m ST (s) Single COD 20° left (s) Single COD 20° right (s) Single COD 40° left (s) Single COD 40° right (s) Single COD 60° left (s) Single COD 60° right (s) Four COD 60° (s)	$r = -0.55$, $p < 0.05$ $r = -0.50$, $p > 0.05$ $r = -0.65$, $p < 0.05$ $r = -0.40$, $p > 0.05$ $r = -0.53$, $p < 0.05$ $r = -0.31$, $p > 0.05$ $r = -0.35$, $p > 0.05$ $r = -0.54$, $p < 0.05$
						SL DJ ** 15cm vertical drop **		Left Leg: 77 ± 14	8m ST (s) Single COD 20° left (s) Single COD 20° right (s) Single COD 40° left (s) Single COD 40° right (s) Single COD 60° left (s) Single COD 60° right (s) Four COD 60° (s)	$r = -0.45$, $p > 0.05$ $r = -0.29$, $p > 0.05$ $r = -0.50$, $p > 0.05$ $r = -0.29$, $p > 0.05$ $r = -0.28$, $p > 0.05$ $r = -0.23$, $p > 0.05$ $r = -0.39$, $p > 0.05$ $r = -0.54$, $p < 0.05$
								Right Leg: 82 ± 14	8m ST (s) Single COD 20° left (s) Single COD 20° right (s) Single COD 40° left (s) Single COD 40° right (s) Single COD 60° left (s) Single COD 60° right (s) Four COD 60° (s)	$r = -0.61$, $p < 0.05$ $r = -0.51$, $p > 0.05$ $r = -0.71$, $p < 0.05$ $r = -0.51$, $p > 0.05$ $r = -0.44$, $p > 0.05$ $r = -0.46$, $p > 0.05$ $r = -0.43$, $p > 0.05$ $r = -0.59$, $p < 0.05$
Young, Miller & Talpey. [101]	n = 24 (24 Males)	18 - 24	180.4 ± 7.2 cm	78.5 ± 9.2	Community level Australian Rules football players, with >2 yrs experience	DJ ** 30cm vertical drop **	JH (cm) / CT (s)	176.3 ± 32.1	Custom COD speed test (s)	$r = -0.645$, $p = 0.001$
Young, Wilson & Byrne. [39]	n = 29 (29 Males)	19 - 34	178.6 ± 7.9 cm	78.5 ± 10.7	>1yr experience in physical activities involving sprinting and/or jumping	DJ ** 30/45/60/75cm vertical drop - best RSI score used for associative analysis **	JH (cm) / CT (s)	203 ± 42	Maximal concentric strength relative to BM (bw) ISOS PF relative to BM (bw)	$r = 0.67$, $p < 0.05$ $r = 0.33$, $p > 0.05$

Notes: n = number; JH = jump height; JD = jump distance; CT = contact time; m = meters; s = seconds; mm = millimetres; ms =milliseconds; DI = division 1, DII = division 2; DIII = division 3 1RM =1 repetition maximum; 3RM = 3 repetition maximum; r_s = spearmans; r = pearsons; ND = not disclosed; CMJ = countermovement jump; DJ = drop jump; SL = single leg; RTD = rate torque development; ST = sprint time; AVG = average; COD = change of direction; PF = peak force; BS = back squat; RE = running economy; COD = change of direction; MVIC = maximal voluntary isometric contraction; ISOS = isometric squat; ISOS = isometric squat; IMTP = isometric mid-thigh pull; bw = body weight; kg = kilograms

Table 5. Meta-Analysis outcomes summary table.

	Summary Effect Estimate (95% CI)	*Z*	*p*	I^2	Q	*p*	Eggars Regression
Strength: Isometric Strength	0.356 (0.209, 0.504)	4.74	< 0.001	0%	3.033	0.695	0.129
Strength: Isotonic Strength	0.365 (0.075, 0.654)	2.47	0.014	66.02%	18.418	0.005	0.951
Strength: Pooled Strength Measures	0.339 (0.209, 0.469)	5.11	< 0.001	27.74%	17.271	0.140	0.283
Endurance Performance	0.401 (0.173, 0.629)	3.45	< 0.001	0%	3.314	0.346	0.074
Sprint Performance: Acceleration	-0.426 (-0.562, -0.290)	-6.14	< 0.001	31.11%	22.992	0.114	0.010
Sprint Performance: Top Speed	-0.326 (-0.502, -0.151)	-3.65	< 0.001	0%	6.351	0.499	0.098
Change of Direction Speed	-0.565 (-0.726, -0.404)	-6.87	< 0.001	56.72%	31.00	0.003	0.029

Note: *Z* = z score, CI = confidence interval

Appendix

PRISMA Checklist [48]

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	Page 1
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	Page 2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	Lines 2-42
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Lines 43-45
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Lines 80-87
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.	Lines 55-68
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Lines 55-68
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.	Lines 55-87
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.	Lines 74-93
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.	Lines 74-162
	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.	Lines 90-121
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.	Lines 100-107
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.	Lines 112-162
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)).	Lines 112-121
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	Lines 112-162

Section and Topic	Item #	Checklist item	Location where item is reported
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	Lines 112-167
	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.	Lines 132-162
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	Lines 170-183
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	Lines 146-183
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	Lines 174-183
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	Lines 146-183
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.	Lines 188-195
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	Lines 188-195
Study characteristics	17	Cite each included study and present its characteristics.	Table 4
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Table 3
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.	Table 4
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	Lines 199-254
	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.	Lines 199-254
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	Lines 199-254
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	Lines 199-254
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	Lines 199-254
Certainty of	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	Lines 199-

Section and Topic	Item #	Checklist item	Location where item is reported
evidence			254
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	Lines 261-269
	23b	Discuss any limitations of the evidence included in the review.	Lines 397-430
	23c	Discuss any limitations of the review processes used.	Lines 397-430
	23d	Discuss implications of the results for practice, policy, and future research.	Lines 434-442
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	Lines 50-52
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	Lines 50-52
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	Lines 50-52
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	Page 1
Competing interests	26	Declare any competing interests of review authors.	Page 1
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.	Table 4 & Lines 188-254