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

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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 $I2$. 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 with 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 to − 0.290]), top speed ($r = -0.326$ [− 0.502 to − 0.151]), and significant large negative associations were noted for change of direction speed ($r = -0.565$ [− 0.726 to − 0.404]). Heterogeneity was trivial to moderate across all measures ($I2$ = 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 that display greater specificity.

Key points

Key Points

- Measures of physical and sporting performance are moderately (strength, speed, endurance performance) and largely (change of direction speed) associated with reactive strength index (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 individual's ability to effectively utilise the stretch shortening cycle (SSC), which is commonly referred to as the ability of 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 et al. [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 et al. [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 that are apparent for drop height within testing processes, which inevitably alters the task and thus the athlete's 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 3 repetition maximum (RM) back squat ($r = -0.18$), in contrast to positive associations for 1RM and 3RM squat in other studies ($r = 0.07$–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 with 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 (22 May 2020) were included. Figure 1 provides a schematic of the search methodology, and filtering strategies. The three-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 that 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.

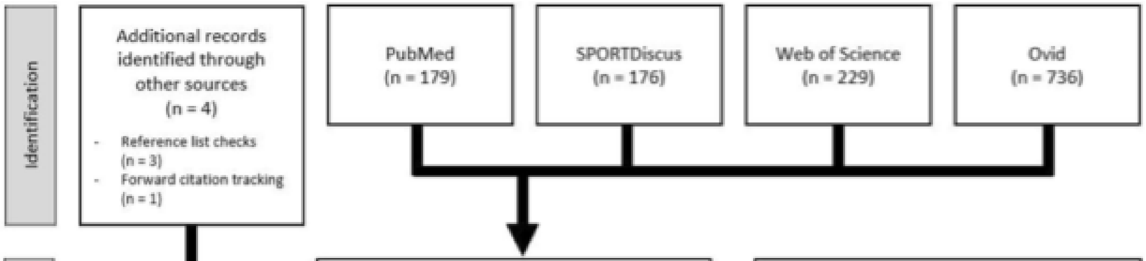

Figure 1 Schematic representing the step-by-step process for the identification and selection of studies, in line with PRISMA recommendations. COD change of direction, CT contact time, FT fight time, JH jump height, RSI reactive strength index

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*

2.3 Screening Strategy and Study Inclusion

All electronic search results were initially exported to ProQuest R 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 forward 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) with 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 with 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.

2.6 Statistical Analysis

Separate 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 < 30 m [56], with data reported in seconds), (7) sprint performance: top speed and speed maintenance (defined as any linear sprint distance/interval of 30–100 m [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 with 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 (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.

Table 2 Questions from the modified Downs and 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[a], standard error[a], confidence intervals[a], or interquartile range[b] 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)?

[a] Normally distributed data

[b] Non-normally distributed data

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 following formula:

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

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

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

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

$$SE_z = \sqrt{V_z}$$

Symmetric 95% CIs around z_r can be calculated based on the following formula:

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

where $z_{c/100}$ is the critical *z* value (where 95% CI = $z0.95 = 1.96$), and $1/\sqrt{(N-3)}$ is the SE_z. To back transform data from z_r to Pearson's *r* for reporting purposes, the following formula was used:

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

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 (e.g., 5, 10, and 20 m 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 (e.g., 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 (e.g., endurance performance where Yo-Yo Intermittent Recovery Test (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' in 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% CIs 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 associated outcome tasks 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 of 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 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 standardised 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 (Fig. 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 four 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 3.

3.2 Methodological Quality and Risk of Bias Assessment

Study methodological quality is shown in Table 4. 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.

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 Figs. 2, 3, 4, 5, 6, 7 and 8.

3.3.1 Strength

Isometric ($r = 0.356$ [95% CI 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.

Table 3 Study characteristics for the studies included within this review

Study	**Participants' characteristics**					**RSI**			**Performance outcome measure**	**Associations with performance**
	n	**Age (years)**	**Height (cm)**	**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 ± 6.3cm DII: 174.3 ± 7.7cm DIII: 171.0 ± 8.0cm	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 and Nolte [89]	n = 15 (15 females)	ND	1.71 ± 0.5m	71.65 ± 9.99	Strength-trained university rugby players (strength training background: 2.67 ± 1.11y)	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 (36 cm vertical drop)		129 ± 22	0–10 m ST (s) 10–30 m ST (s) 30–60 m ST (s)	r = –0.01, p>0.05 r = –0.27, p>0.05 r = 0.01, p>0.05
						DJ (48 cm vertical drop)		127 ± 26	0–10 m ST (s) 10–30 m ST (s) 30–60 m ST (s)	r = –0.20, p>0.05 r = –0.51, p>0.05 r = –0.33, p>0.05
						DJ (60 cm vertical drop)		112 ± 23	0–10 m ST (s) 10–30 m ST (s) 30–60 m ST (s)	r = –0.14, p>0.05 r = –0.33, p>0.05 r = –0.15, p>0.05
						DJ (72 cm vertical drop)		110 ± 20	0–10 m ST (s) 10–30 m ST (s) 30–60 m ST (s)	r = –0.30, p>0.05 r = –0.56, p<0.05 r = –0.42, p>0.05
						DJ (84 cm vertical drop)		97 ± 25	0–10 m ST (s) 10–30 m ST (s) 30–60 m ST (s)	r = –0.25, p>0.05 r = –0.57, p<0.05 r = –0.42, p>0.05
Barr and 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 y)	DJ (24 cm vertical drop)	JH (cm)/CT (s)	132 ± 26	1RM front squat relative to BM (kg)	r = 0.15, (95% CI−0.31 to 0.56)
						DJ (36 cm vertical drop)		129 ± 20	1RM front squat relative to BM (kg)	r = 0.44 (95% CI 0.0 to 0.74)
						DJ (48 cm vertical drop)		127 ± 25	1RM front squat relative to BM (kg)	r = 0.6 (95% CI 0.21 to 0.82)
						DJ (60 cm vertical drop)		114 ± 17	1RM front squat relative to BM (kg)	r = 0.33 (95% CI−0.13 to 0.67)

Study	Participants' characteristics					RSI			Performance outcome measure	Associations with performance
	n	Age (years)	Height (cm)	Body mass (kg)	Training status	Test utilised	Calculation method	Value		
						DJ (72 cm vertical drop)		110 ± 17	1RM front squat relative to BM (kg)	r = 0.7 (95% CI 0.37 to 0.87)
						DJ (84 cm vertical drop)		97 ± 24	1RM front squat relative to BM (kg)	r = 0.47 (95% CI 0.04 to 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 (30 cm vertical drop)	JH (m)/CT (s)	ND	IMTP PF (N) IMTP PF relative to BM ($N\ kg^{-1}$) IMTP PF allometrically scaled ($N/kg^{0.67}$)	r = 0.302, p<0.05 r = 0.289, p>0.05 r = 0.289, p>0.05
						DJ (40 cm vertical drop)		ND	IMTP PF (N) IMTP PF relative to BM ($N\ kg^{-1}$) 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 (50 cm vertical drop)		ND	IMTP PF (N) IMTP PF relative to BM ($N\ kg^{-1}$) IMTP PF allometrically scaled ($N/kg^{0.67}$)	r = 0.327, p<0.01 r = 0.360, p<0.01 r = 0.382, p<0.01
						DJ (60 cm vertical drop)		ND	IMTP PF (N) IMTP PF relative to BM ($N\ kg^{-1}$) 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 mo)	SL DJ (30 cm vertical drop; ACLR limb used)	JH (m)/CT (s)	0.2 ± 0.1	MVIC knee extension RTD ($Nm\ s^{-1}$) MVIC knee extension RTD 100 ms ($Nm\ s^{-1}$) MVIC knee extension RTD 200 ms ($Nm\ s^{-1}$) 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 et al. [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 y competing at this level)	DJ (30 cm vertical drop)	JH/CT	1.78 ± 0.35	20 m ST (s)	r = −0.495, p>0.05

Study	Participants' characteristics					RSI			Performance outcome measure	Associations with performance
	n	Age (years)	Height (cm)	Body mass (kg)	Training status	Test utilised	Calculation method	Value		
Cronin and 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 (40 cm vertical drop)	JH (cm)/CT (s)	ND	5 m ST (s) 10 m ST (s) 30 m ST (s) Squat 3RM (kg) Quadriceps peak torque 60 deg s^{-1} (N m^{-1}) Hamstrings peak torque 60 $°·s^{-1}$ (N m^{-1}) Quadriceps peak torque 300 ° s^{-1} (N m^{-1}) Hamstrings peak torque 300 $°·s^{-1}$ (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>2 y)	DJ (40 cm vertical drop)	FT/CT (s)	ND	1RM squat relative to BM (kg kg^{-1}) 10 m ST (s) Flying (20 m approach) 10 m 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 (30 cm vertical drop)	JH (m)/CT (s)	1.04 ± 0.23	505 CODs dominant limb (s) 505 CODs nondominant 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 and field sprinters: 23 ± 5	Team sport athletes: 172 ± 4 cm Trained track and field sprinters: 177 ± 9 cm	Team sport athletes: 72.8 ± 8.0 Trained track and field sprinters: 73.6 ± 10.2	Trained team sport athletes (n=13) and highly trained track and field sprinters (n=11; IAAF Points: 1039 ± 59)	DJ (50 cm 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 to 0.79)
Furlong et al. [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 (30 cm vertical drop)	JH (m)/CT (ms)	0.894 ± 0.203	1RM BS relative to BM (kg kg^{-1}) 30 m 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) and international (7 males,	DJ (30 cm vertical drop)	JH (m)/CT (s)	Males: 2.06 ± 0.43	0–10 m ST (s) 10–20 m ST (s) 20–30 m ST (s)	r = −0.03, p>0.05 r = 0.01, p>0.05 r = 0.14, p>0.05

Study	Participants' characteristics					RSI			Performance outcome measure	Associations with performance
	n	Age (years)	Height (cm)	Body mass (kg)	Training status	Test utilised	Calculation method	Value		
					8 females) level sprinters (>2 years sprint and plyometric training experience)				30–40 m ST (s) 40 m ST (s) IMTP PF (N) IMTP relative PF (N kg^{-1})	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 (30 cm vertical drop)		Females: 1.65 ± 0.35	0–10 m ST (s) 10–20 m ST (s) 20–30 m ST (s) 30–40 m ST (s) 40 m 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>3 y (touch football, rugby, basketball), with general resistance training experience	SL horizontal DJ (20 cm vertical drop, into jump for max distance. Average of best L and R trials used in analysis)	JD (cm)/CT (s)	430 ± 79	0–5 m ST (s) 0–10 m ST (s) 0–25 m ST (s) 5–10 m ST (s) 10–25 m 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 (30 cm vertical drop)	JH (m)/CT	Backs: 0.87 ± 0.31 Forwards: 0.58 ± 0.13	5 m ST (s) 10 m ST (s) 20 m ST (s) 30 m ST (s) 40 m 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 (5000 m, 10,000 m, marathon), with>4 y long-distance training experience	DJ (40 cm 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,	DJ (40 cm vertical drop)	FT (s)/CT (s)	1.771 ± 0.400	0–10 m ST (s) 0–20 m ST (s) 0–40 m ST (s) T test COD (s)	r = −0.690, p = 0.003 r = −0.577, p = 0.019

Study	**Participants' characteristics**					**RSI**			**Performance outcome measure**	**Associations with performance**
	n	**Age (years)**	**Height (cm)**	**Body mass (kg)**	**Training status**	**Test utilised**	**Calculation method**	**Value**		
					Australian football, touch, Oztag)				COD and acceleration test (s)	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	0–10 m ST (s) 0–20 m ST (s) 0–40 m ST (s) T test COD (s) COD and 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 and field athletes (4 long jumpers, 15 sprinters)	DJ (45 cm vertical drop)	JH (cm)/CT (ms)	Males: 1.08 ± 0.33 Females: 1.17 ± 0.31	10 m ST (s) 20 m ST (s) 40 m ST (s) 60 m 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 (75 cm vertical drop)		Males: 1.04 ± 0.27 Females: 1.03 ± 0.26	10 m ST (s) 20 m ST (s) 40 m ST (s) 60 m 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 (18 cm 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 (30 cm vertical drop)	JH (mm)/CT (ms)	2.05 ± 0.45	3RM squat (kg) 5 s lateral shuffle test L (n) 5 s 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 (20 cm vertical drop; average of L&R limbs used for RSI value)	JH (m)/CT (s)	L&R pooled: 1.16 ± 0.50	10 m ST (s) 25 m ST (s)	r = 0.16, p>0.05 r = −0.02, p>0.05
						SL horizontal DJ (20 cm vertical drop; average of L&R limbs used for RSI value)	JD (m)/CT (s)	L&R pooled: 4.11 ± 1.32	10 m ST (s) 25 m ST (s)	r = 0.08, p>0.05 r = −0.49, p>0.05

Study	Participants’ characteristics					RSI			Performance outcome measure	Associations with performance
	n	Age (years)	Height (cm)	Body mass (kg)	Training status	Test utilised	Calculation method	Value		
Nagahara et al. [95]	n = 19 (19 males)	20.1 ± 1.2	1.75 ± 0.04 m	66.1 ± 4.0	Male sprinters (100 m PB: 11.19 ± 0.34 s, ranging from 10.72 to 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	60 m 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	60 m 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 (40 cm vertical drop)	FT/CT (ms)	2.50 ± 0.47	5 m ST (s)	r = −0.121, p>0.05
									10 m ST (s)	r = −0.165, p>0.05
									20 m ST (s)	r = −0.167, p>0.05
									Preplanned multidirectional sprinting L (s)	r = −0.145, p>0.05
									Preplanned multidirectional sprinting R (s)	r = −0.150, p>0.05
						SL DJ (20 cm vertical drop)		Left leg: 1.35 ± 0.23	5 m ST (s)	r = −0.227, p>0.05
									10 m ST (s)	r = −0.320, p>0.05
									20 m ST (s)	r = −0.256, p>0.05
									Preplanned multidirectional sprinting L (s)	r = −0.243, p>0.05
									Preplanned multidirectional sprinting R (s)	r = −0.274, p>0.05
								Right leg: 1.38 ± 0.25	5 m ST (s)	r = −0.239, p>0.05
									10 m ST (s)	r = −0.336, p>0.05
									20 m ST (s)	r = −0.309, p>0.05
									Preplanned multidirectional sprinting L (s)	r = −0.201, p>0.05
									Preplanned multidirectional sprinting R (s)	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 and Herzegovina	DJ (40 cm vertical drop)	JH/CT	1.58 ± 0.30	Basketball-specific COD speed (s)	r = −0.64, p<0.05

Study	**Participants' characteristics**					**RSI**			**Performance outcome measure**	**Associations with performance**
	n	**Age (years)**	**Height (cm)**	**Body mass (kg)**	**Training status**	**Test utilised**	**Calculation method**	**Value**		
Salonikidis and 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 (20 cm vertical drop)	JH (cm)/CT (s)	125.3 ± 45.2	4-m forward sprint speed trained limb (s) 4-m forward sprint speed untrained limb (s) 12-m forward sprint speed trained limb (s) 12-m forward sprint speed untrained limb (s) 12-m forward sprint with turn speed trained limb (s) 12-m 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 (20 cm vertical drop)		Trained leg: 50.1 ± 19.6	4-m forward sprint speed trained limb (s) 12-m forward sprint speed trained limb (s) 12-m 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	4-m forward sprint speed untrained limb (s)	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

Study	Participants' characteristics					RSI			Performance outcome measure	Associations with performance
	n	Age (years)	Height (cm)	Body mass (kg)	Training status	Test utilised	Calculation method	Value		
									12-m forward sprint speed untrained limb (s) 12-m forward sprint with turn speed untrained limb (s) Seated isometric bilateral PF (N) Seated isometric unilateral PF untrained limb (N)	
Schuster and 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 >2 y resistance training experience	SL DJ (20 cm vertical drop: average of L&R limbs used for RSI value)	JH (m)/CT (s)	0.99 ± 0.06	5 m ST (s) 10 m ST (s) 15 m ST (s) 20 m ST (s) 5–10 m ST (s) 10–15 m ST (s) 15–20 m 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 (20 cm vertical drop, into jump for max distance; average of L&R limbs used for RSI value)	JD (m)/CT (s)	4.42 ± 0.35	5 m ST (s) 10 m ST (s) 15 m ST (s) 20 m ST (s) 5–10 m ST (s) 10–15 m ST (s) 15–20 m 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 (100 m PB: 11.71 ± 0.53 s)	DJ (40 cm vertical drop)	JH (cm)/CT (s)	215.3 ± 36.9	10 m ST (s) 30 m ST (s) 60 m ST (s) 100 m 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 et al. [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 and International competitions)	DJ (40 cm vertical drop)	JH (cm)/CT (s)	1.4 ± 0.54	Fencing-specific test: 5 m Shuttle test (s) Fencing-specific test: 5 m Shuttle test relative to BM ($s.kg^{-1}$)	$r = -0.44$, (95% CI-0.70 to-0.08) $r = -0.56$, (95% CI-0.77 to-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 and junior fencers (8.5 ± 4.2 y fencing experience)	DJ (30 cm 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:	England squash performance programme athletes, world ranked from 3 to 364	DJ (30 cm vertical drop)	JH (cm)/CT (s)	Males: 291 ± 45 294 ± 51 235 ± 54	Squash-specific multiple sprint ability (s) Squash-specific CODs (s)	$r = -0.69, p<0.01$ $r = -0.53, p = 0.02$ $r = 0.29, p = 0.29$

Study	Participants' characteristics					RSI			Performance outcome measure	Associations with performance
	n	Age (years)	Height (cm)	Body mass (kg)	Training status	Test utilised	Calculation method	Value		
				62.5 ± 3.1 58.4 ± 1.7 66.2 ± 9.1	Full-time senior squad players (n=12) Full-time transition squad players (n=7) Talented athlete scholarship scheme (n=12)				Estimated VO_{2max} (mL kg^{-1} min^{-1})	
								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 et al. [83]	n = 15 (15 males)	18–28	1.75 ± 0.08 m	74.6 ± 12.6	Competitively involved in sport requiring CODs (comprising soccer, basketball, Australian football, tennis)	DJ (30 cm vertical drop)	JH (cm)/CT (s)	195 ± 46	8 m 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 (15 cm vertical drop)		Left leg: 77 ± 14	8 m 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	8 m ST (s) Single COD 20° left (s) Single COD 20° right (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

Study	Participants' characteristics					RSI			Performance outcome measure	Associations with performance
	n	Age (years)	Height (cm)	Body mass (kg)	Training status	Test utilised	Calculation method	Value		
									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 = −0.46, p >0.05 r = −0.43, p >0.05 r = −0.59, p <0.05
Young et al. [101]	n = 24 (24 males)	18–24	180.4 ± 7.2 cm	78.5 ± 9.2	Community level Australian Rules football players, with >2 y experience	DJ (30 cm vertical drop)	JH (cm)/CT (s)	176.3 ± 32.1	Custom COD speed test (s)	r = −0.645, p = 0.001
Young et al. [39]	n = 29 (29 males)	19–34	178.6 ± 7.9 cm	78.5 ± 10.7	>1 y experience in physical activities involving sprinting and/or jumping	DJ (30/45/60/75 cm 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

1RM 1 repetition maximum, 3RM 3 repetition maximum, AVG average, BM body mass, BS back squat, bw body weight, CMJ countermovement jump, COD change of direction, CT contact time, DI division 1, DII division 2, DIII division 3, DJ drop jump, FT fight time, IMTP isometric mid-thigh pull, IRT Intermittent Recovery Test, ISOS isometric squat, JD jump distance, JH jump height, kg kilograms, L left, m meters, mm millimetres, ms milliseconds, MVIC maximal voluntary isometric contraction, n number, ND not disclosed, PB personal best, PF peak force, r Pearsons, R right, RE running economy, r_s Spearmans, RSI reactive strength index, RTD rate torque development, s seconds, SL single leg, ST sprint time

Table 4 Results of study

Study	Downs and 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 and Nolte [89]	+	+	+	+	+	-	?	+	+	+	8
Barr and Nolte [46]	+	+	+	+	+	-	?	+	+	+	8
Beattie et al. [31]	+	+	+	+	-	-	?	+	+	+	7
Birchmeier et al. [90]	+	+	+	+	+	-	?	+	+	+	8
Carr et al. [91]	+	-	+	+	+	-	?	+	+	+	7
Cronin and Hansen [37]	+	+	+	+	-	-	?	+	+	+	7
Cunningham et al. [47]	+	-	+	+	-	-	?	+	+	+	6
Delaney et al. [92]	+	+	+	+	+	-	?	+	+	+	8
Douglas et al. [33]	+	+	+	+	+	-	?	+	+	+	8
Furlong et al. [38]	+	+	+	+	+	-	?	+	+	+	8
Healy et al. [34]	+	+	+	+	+	-	?	+	+	+	8
Holm et al. [87]	+	+	+	+	+	-	?	+	+	+	8
Jones et al. [43]	+	-	+	+	+	+	+	+	+	+	9
Li et al. [74]	+	+	+	+	+	+	?	+	+	+	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 and Zafeiridis [35]	+	+	+	+	+	-	?	+	+	+	8
Schuster and Jones [85]	+	+	+	+	+	-	?	+	+	+	8
Smirniotou et al. [98]	+	+	+	+	+	-	?	+	+	+	8
Tsolakis et al. [99]	+	+	+	+	+	-	?	+	+	+	8
Turner et al. [100]	+	+	+	+	+	-	?	+	+	+	8
Wilkinson et al. [44]	+	+	+	+	+	+	+	+	+	+	10
Young et al. [83]	+	+	+	+	+	-	?	+	+	+	8
Young et al. [101]	+	+	+	+	+	+	?	+	+	+	9
Young et al. [39]	+	+	+	+	+	-	?	+	+	+	8

+ yes, − no, ? unable to determine

Table 5 Meta-analysis outcomes summary table

	Summary effect estimate (95% CI)	Z	p	1^2	Q	p	Egger's regression
Strength: isometric strength	0.356 (0.209 to 0.504)	4.74	<0.001	0%	3.033	0.695	0.129
Strength: isotonic strength	0.365 (0.075 to 0.654)	2.47	0.014	66.02%	18.418	0.005	0.951
Strength: pooled strength measures	0.339 (0.209 to 0.469)	5.11	<0.001	27.74%	17.271	0.140	0.283
Endurance performance	0.401 (0.173 to 0.629)	3.45	<0.001	0%	3.314	0.346	0.074
Sprint performance: acceleration	−0.426 (−0.562 to−0.290)	-6.14	<0.001	31.11%	22.992	0.114	0.010
Sprint performance: top speed	−0.326 (−0.502 to−0.151)	-3.65	<0.001	0%	6.351	0.499	0.098
Change of direction speed	−0.565 (−0.726 to−0.404)	-6.87	<0.001	56.72%	31.00	0.003	0.029

CI confidence interval, p p value, Z score

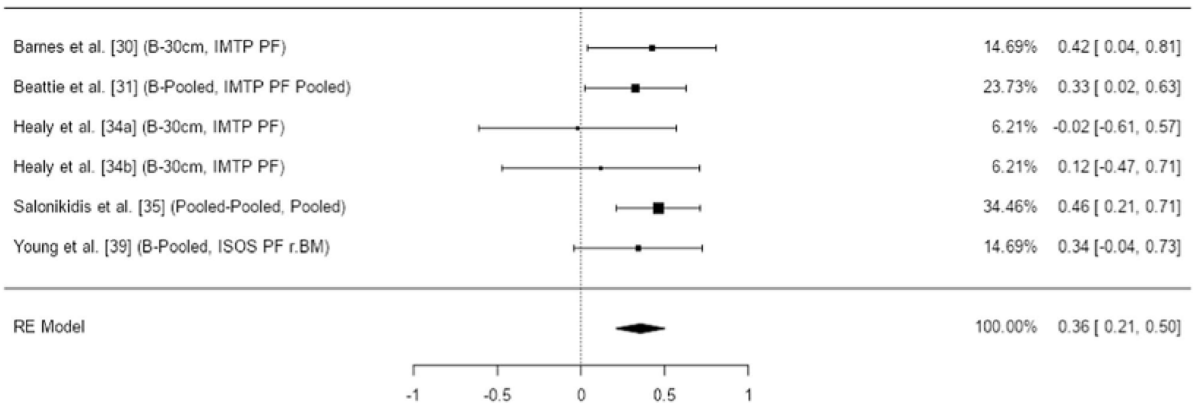

Figure 2 Forest plot outlining the association between RSI and isometric strength. BM body mass, IMTP isometric mid-thigh pull, ISOS isometric squat, PF peak force, RE random effects, RSI reactive strength index

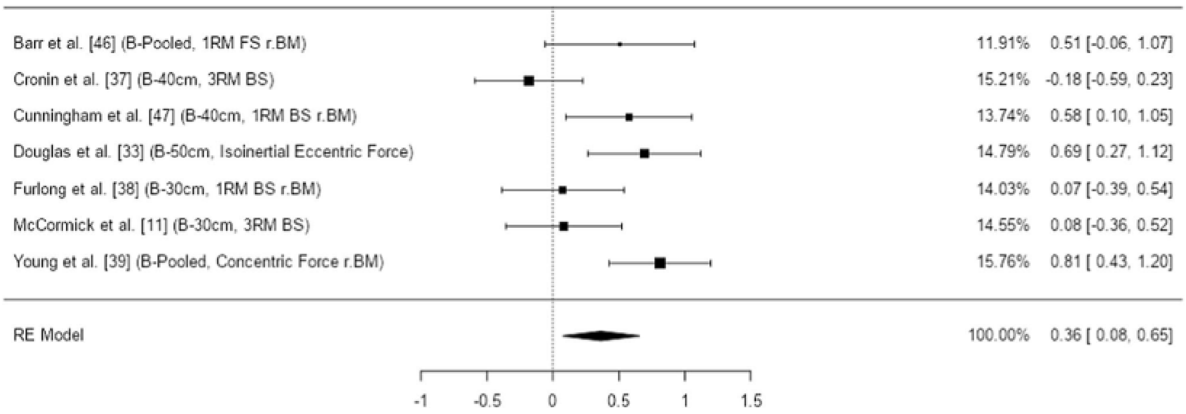

Figure 3 Forest plot outlining the association between RSI and isotonic strength (inclusive of isoinertial). BM body mass, BS back squat, FS front squat, RE random effects, RM repetition maximum, RSI reactive strength index

When all measures of strength were pooled, analyses indicated a significant association with RSI (r = 0.339 [95% CI 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).

3.3.2 Endurance Performance

Endurance performance was significantly associated with RSI (r = 0.401 [95% CI 0.173–0.629], Z = 3.45; p < 0.001). Tests for heterogeneity were identified as trivial (I2 = 0%, Q = 3.314, p = 0.346), and there was no evidence of small study bias (p = 0.074).

3.3.3 Speed

Acceleration (r = − 0.426 [95% CI − 0.562 to − 0.290], Z = − 6.14; p < 0.001) and top speed (r = − 0.326 [95% CI − 0.502 to − 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 Fig. 9. There was no evidence of small study bias for top speed (p = 0.098).

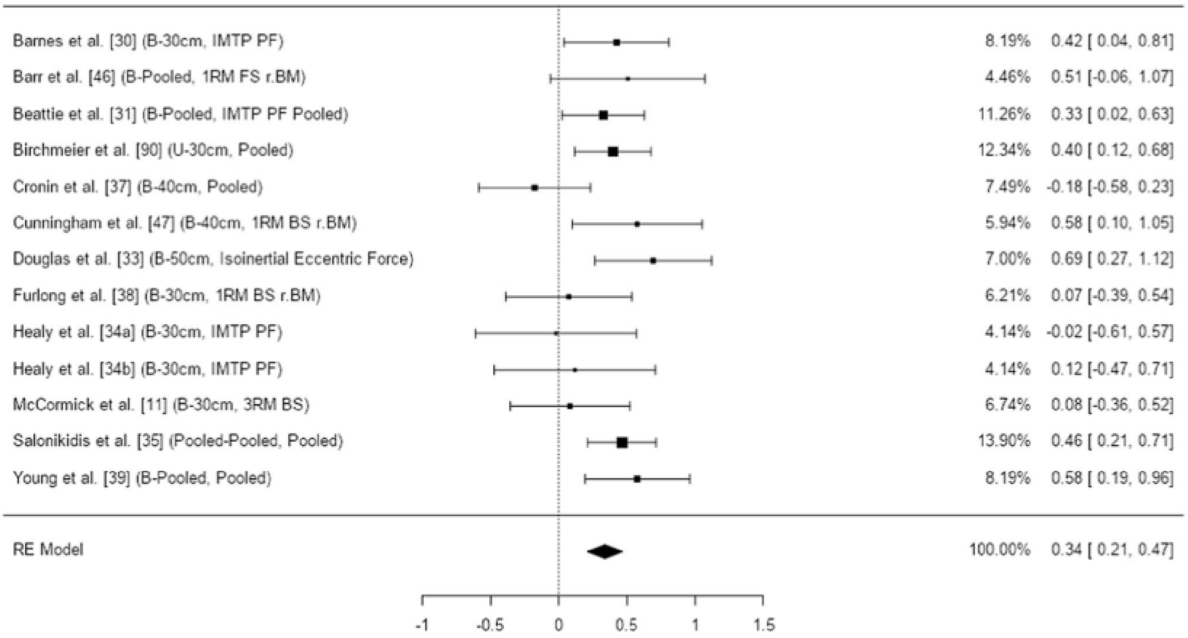

Figure 4 Forest plot outlining the association between RSI and all strength measures pooled. BM body mass, BS back squat, FS front squat, IMTP isometric mid-thigh pull, PF peak force, RE random effects, RM repetition maximum, RSI reactive strength index

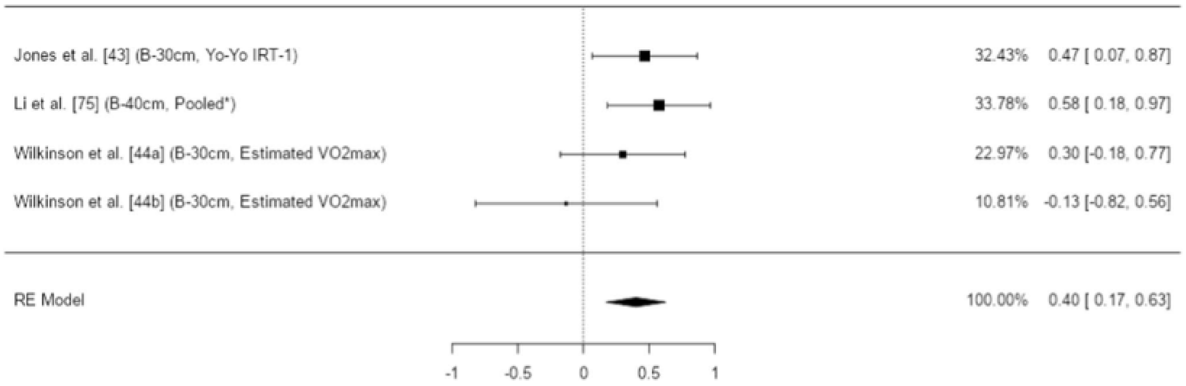

Figure 5 Forest plot outlining the association between RSI and endurance performance, where *data positively transformed. IRT Intermittent Recovery Test, RE random effects, RSI reactive strength index

3.3.4 Change of Direction Speed

COD speed was significantly associated with RSI ($r = -0.565$ [95% CI − 0.726 to − 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 Fig. 10.

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.

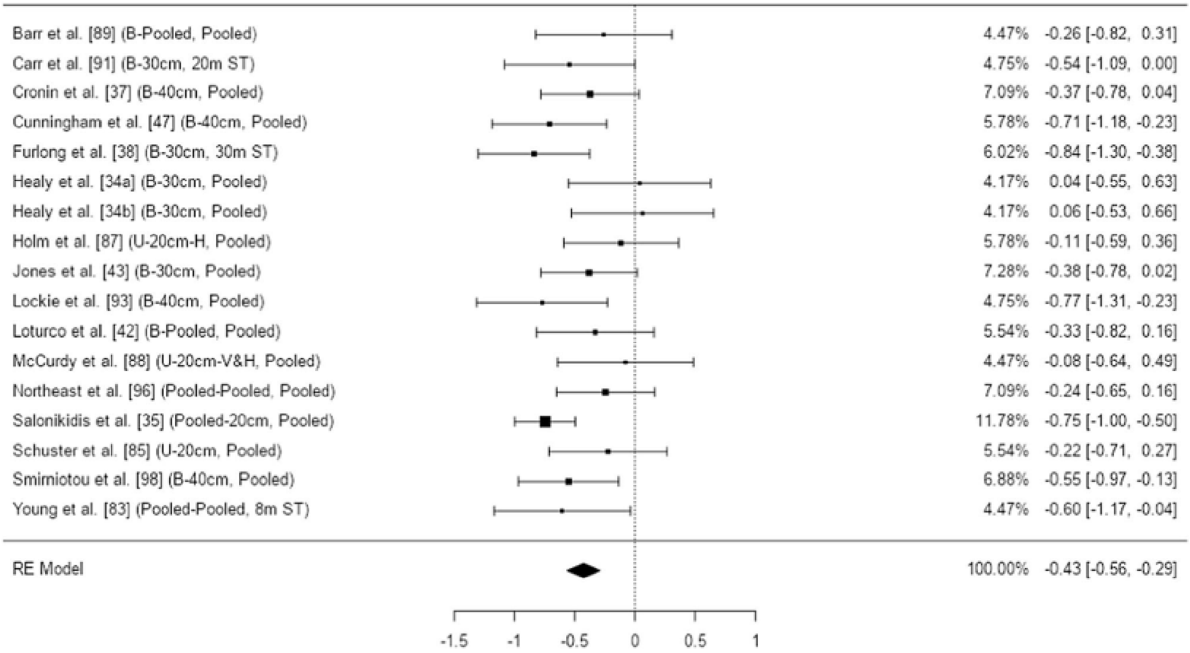

Figure 6 Forest plot outlining the association between RSI and sprint performance: acceleration. H horizontal, RE random effects, RSI reactive strength index, ST sprint time, V vertical

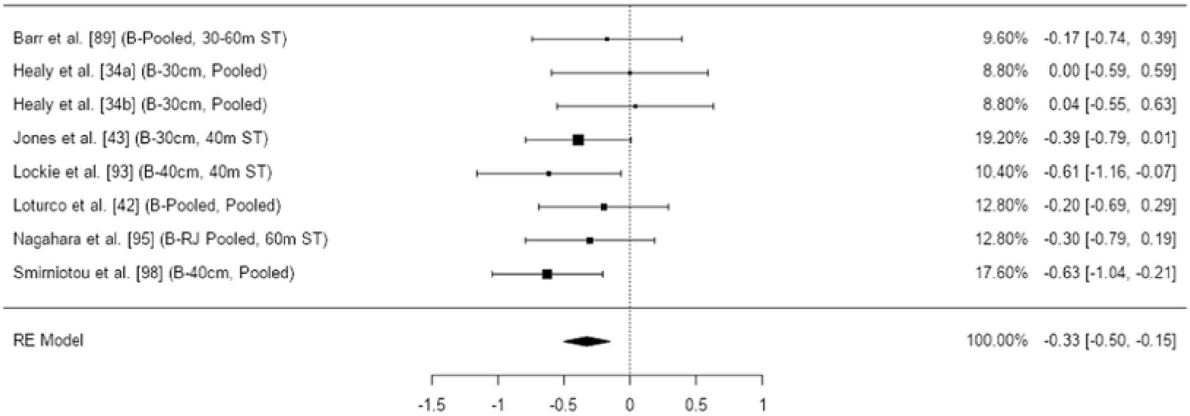

Figure 7 Forest plot outlining the association between RSI and sprint performance: top speed. B-RJ bilateral rebound jumps, RE random effects, RSI reactive strength index, ST sprint time

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 [34, 37]. Healy et al. [34] 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 1RM of twice bodyweight being a potential threshold indicative of a greater performance in athletic tasks [66]. Cronin and Hansen [37] reported approximately 1.73–1.94 $kg.kg^{-1}$ body mass of relative strength within a 3RM back squat (calculated for illustration based on group average values), and Healy et al. [34] reported 36.3 ± 6.2 $N. kg^{-1}$ within the isometric mid-thigh pull relative to body mass (approximately 3.5–3.75 × 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. [34] appear to contradict such evidence ($r = -0.18$ and -0.02, respectively). Jimenez-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.

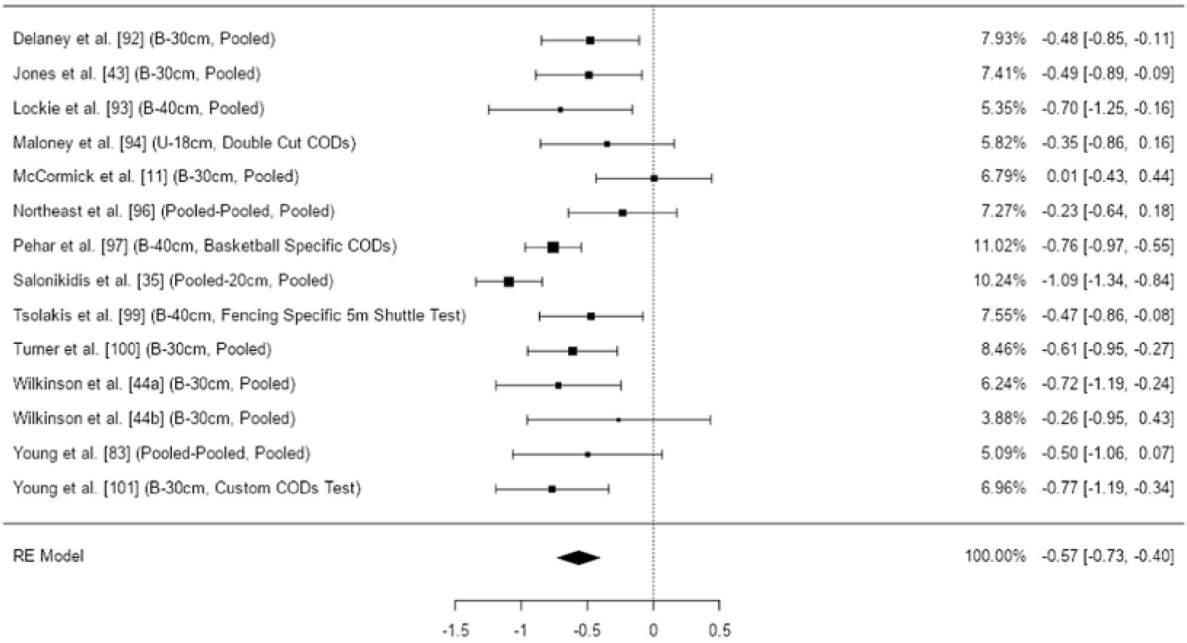

Figure 8 Forest plot outlining the association between RSI and change of direction speed. COD change of direction, RE random effects, RSI reactive strength index

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.

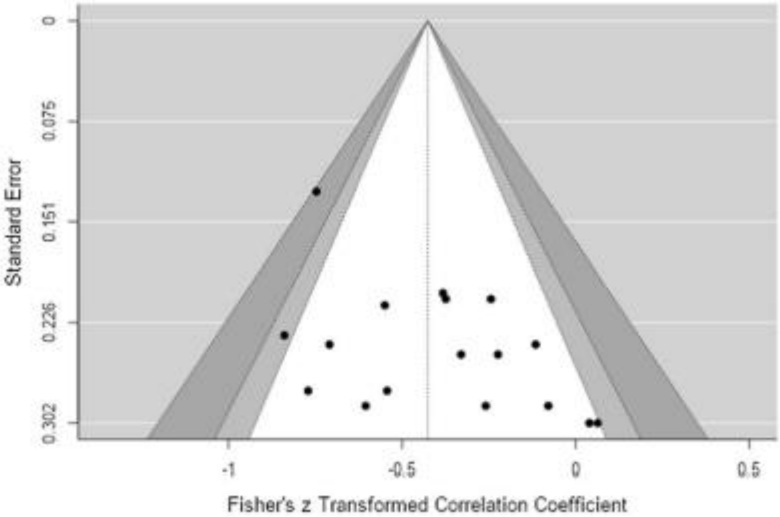

Figure 9 Funnel plot presenting Fisher’s z transformed correlation coefficient data for sprint performance: acceleration, plotted against its standard error

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 et al. [43] and Wilkinson et al. [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・kg^{-1}・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 with 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 the 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.

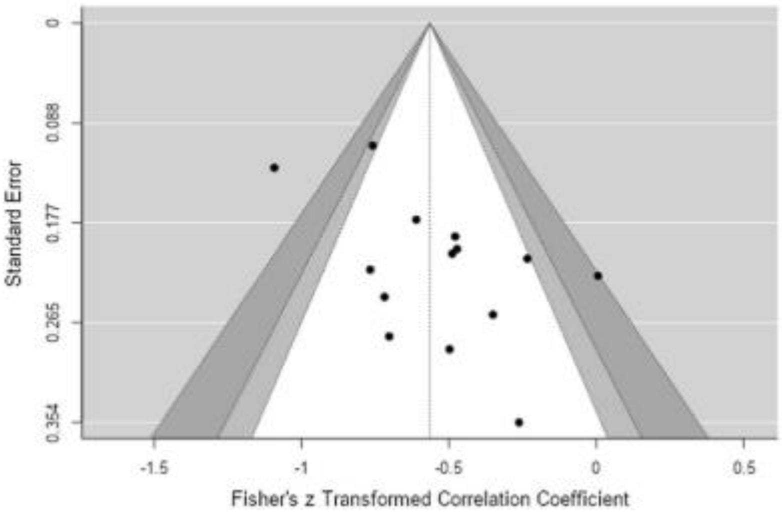

Figure 10 Funnel plot presenting Fisher's z transformed correlation coefficient data for change of direction speed, plotted against its standard error

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 ($r = -0.426$ [95% CI − 0.562 to − 0.290]), compared with top speed ($r = -0.326$ [95% CI − 0.502 to − 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, Jimenez-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 et al. [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 with 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, research is needed to further examine this concept from both a kinetic and kinematic perspective.

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 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 that 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 with 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 with 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 elucidate the strength of these relationships more clearly.

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, 30, 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. Task 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 (e.g., 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 (jump height: m, cm, mm; flight time: s, ms; contact time: 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. Twenty-six studies reported RSI relative to jump displacement (either jump height or jump distance), with five 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 (e.g., 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 of a horizontal index for RSI, given the relative importance of task specificity.

Declarations

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Conflict of interest Paul Jarvis, Anthony Turner, Paul Read and Chris Bishop declare that they have no conflicts of interest relevant to the content of this review.

Author contributions 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 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.

References

1. Komi PV. Stretch-shortening cycle: a powerful model to study normal and fatigued muscle. J Biomech. 2000;33(10):1197–206.
2. Newton RU, Laursen PB, Young W. Clinical exercise testing and assessment of athletes. In: Olympic textbook of medicine in sport. Oxford: Wiley-Blackwell; 2008. p. 160–99.
3. Nicol C, Avela J, Komi PV. The stretch–shortening cycle: a model to study naturally occurring neuromuscular fatigue. Sports Med. 2006;36:977–99.
4. Wilson JM, Flanagan EP. The role of elastic energy in activities with high force and power requirements: a brief review. J Strength Cond Res. 2008;22(5):1705–15.
5. Cavagna GA, Saibene FP, Margaria R. Effect of negative work on the amount of positive work performed by an isolated muscle. J Appl Physiol. 1965;20(1):157–8.
6. Cavagna GA, Dusman B, Margaria R. Positive work done by a previously stretched muscle. J Appl Physiol. 1968;24(1):21–32.
7. Schenau GJVI, Bobbert MF, de Haan A. Mechanics and energetics of the stretch-shortening cycle: a stimulating discussion. J Appl Biomech. 1997;13(4):484–96.
8. Zatsiorsky VM. Science and practice of strength training. Champaign: Human Kinetics; 1995.
9. Turner AN, Jeffreys I. The stretch-shortening cycle: proposed mechanisms and methods for enhancement. Strength Cond J. 2010;32(4):87–99.
10. Schmidtbleicher D. Training for power events. In: Komi PV, editor. The encyclopedia of sports medicine. Vol. 3: strength and power in sport. Oxford: Blackwell; 1992. p. 169–79.
11. McCormick BT, Hannon JC, Hickslittle CA, Newton M, Shultz B, Detling N, Young WB. The relationship between change of direction speed in the frontal plane, power, reactive strength, and strength. Int J Exerc Sci. 2014;7(4):260–70. 12. de Villarreal ES, Requena B, Cronin JB. The effects of plyometric training on sprint performance: a meta-analysis. J Strength Cond Res. 2012;26(2):575–84.
13. Bobbert MF, Casius LJR. Is the effect of a countermovement on jump height due to active state development? Med Sci Sports Exerc. 2005;37(3):440–6.
14. Voigt M, Bojsen-Moller F, Simonsen EB, Dyhre-Poulsen P. The influence of tendon Youngs modulus, dimensions and instantaneous moment arms on the efficiency of human movement. J Biomech. 1995;28(3):281–91.
15. Marshall BM, Moran KA. Which drop jump technique is most effective at enhancing countermovement jump ability, “countermovement” drop jump or “bounce” drop jump? J Sports Sci. 2013;31(12):1368–74.
16. Di Giminiani R, Petricola S. The power output-drop height relationship to determine the optimal dropping intensity and to monitor the training intervention. J Strength Cond Res. 2016;30(1):117–25.
17. Young W. Laboratory strength assessment of athletes. New Stud Athl. 1995;10:89–89.
18. Markwick WJ, Bird SP, Tufano JJ, Seitz LB, Haff GG. The intraday reliability of the reactive strength index calculated from a drop jump in professional men’s basketball. Int J Sports Physiol Perform. 2015;10(4):482–8.
19. McMahon JJ, Suchomel TJ, Lake JP, Comfort P. Relationship between reactive strength index variants in rugby league players. J Strength Cond Res. 2021;35(1):280–5.
20. Byrne DJ, Browne DT, Byrne PJ, Richardson N. Interday reliability of the reactive strength index and optimal drop height. J Strength Cond Res. 2017;31(3):721–6.
21. Feldmann CR, Weiss LW, Ferreira LC, Schilling BK, Hammond KG. Reactive strength index and ground contact time: reliability, precision, and association with drop vertical jump displacement. J Strength Cond Res. 2011;25:S1.
22. Flanagan EP, Ebben WP, Jensen RL. Reliability of the reactive strength index and time to stabilization during depth jumps. J Strength Cond Res. 2008;22(5):1677–82.
23. Lloyd RS, Oliver JL, Hughes MG, Williams CA. Reliability and validity of field-based measures of leg stiffness and reactive strength index in youths. J Sports Sci. 2009;27(14):1565–73.
24. Flanagan EP. An examination of the slow and fast stretch shortening cycle in cross country skiers and runners. In: Proceedings of the XXV International Symposium of Biomechanics in Sports. H.-J. Menzel and MH Chagas, eds. Ouro Preto, Brazil, pp. 23–27, 2007.
25. Harper D, Hobbs S, Moore J. The 10 to 5 repeated jump test. A new test for evaluating reactive strength. In: British Association of Sports and Exercise Sciences Student Conference, 2011.

26. Chelly SM, Denis C. Leg power and hopping stiffness: relationship with sprint running performance. Med Sci Sports Exerc. 2001;33(2):326–33.
27. Hobara H, Inoue K, Omuro K, Muraoka T, Kanosue K. Determinant of leg stiffness during hopping is frequency-dependent. Eur J Appl Physiol. 2011;111(9):2195–201.
28. Lockie RG, Murphy AJ, Knight TJ, De Jonge XAJ. Factors that differentiate acceleration ability in field sport athletes. J Strength Cond Res. 2011;25(10):2704–14.
29. Dos'Santos T, Thomas C, Comfort P, Jones PA. The effect of angle and velocity on change of direction biomechanics: an angle-velocity trade-off. Sports Med. 2018;48(10):2235–53.
30. Barnes JL, Schilling BK, Falvo MJ, Weiss LW, Creasy AK, Fry AC. Relationship of jumping and agility performance in female volleyball athletes. J Strength Cond Res. 2007;21(4):1192.
31. Beattie K, Carson BP, Lyons M, Kenny IC. The relationship between maximal strength and reactive strength. Int J Sports Physiol Perform. 2017;12(4):548–53.
32. Barker LA, Harry JR, Mercer JA. Relationships between countermovement jump ground reaction forces and jump height, reactive strength index, and jump time. J Strength Cond Res. 2018;32(1):248–54.
33. Douglas J, Pearson S, Ross A, McGuigan M. Reactive and eccentric strength contribute to stiffness regulation during maximum velocity sprinting in team sport athletes and highly trained sprinters. J Sports Sci. 2020;38(1):29–37.
34. Healy R, Smyth C, Kenny IC, Harrison AJ. Influence of reactive and maximum strength indicators on sprint performance. J Strength Cond Res. 2019;33(11):3039–48.
35. Salonikidis K, Zafeiridis A. The effects of plyometric, tennis-drills, and combined training on reaction, lateral and linear speed, power, and strength in novice tennis players. J Strength Cond Res. 2008;22(1):182–91.
36. Kipp K, Kiely MT, Giordanelli MD, Malloy PJ, Geiser CF. Biomechanical determinants of the reactive strength index during drop jumps. Int J Sports Physiol Perform. 2018;13(1):44–9.
37. Cronin JB, Hansen KT. Strength and power predictors of sports speed. J Strength Cond Res. 2005;19(2):349–57.
38. Furlong LA, Harrison AJ, Jensen RL. Measures of strength and jump performance can predict 30-m sprint time in rugby union players. J Strength Cond Res. 2021;35(9):2579–83.
39. Young W, Wilson G, Byrne C. Relationship between strength qualities and performance in standing and run-up vertical jumps. J Sports Med Phys Fit. 1999;39(4):285–93.
40. McMahon JJ, Jones PA, Comfort P. Comparison of countermovement jump–derived reactive strength index modified and underpinning force-time variables between super league and championship rugby league players. J Strength Cond Res. 2019. https://doi.org/10.1519/JSC.0000000000003380.
41. Kipp K, Kiely MT, Geiser CF. Reactive strength index modified is a valid measure of explosiveness in collegiate female volleyball players. J Strength Cond Res. 2016;30(5):1341–7.
42. Loturco I, Kobal R, Kitamura K, Fernandes V, Moura N, Siqueira F, Cal Abad CC, Pereira LA. Predictive factors of elite sprint performance: influences of muscle mechanical properties and functional parameters. J Strength Cond Res. 2019;33(4):974–86.
43. Jones B, Emmonds S, Hind K, Nicholson G, Rutherford Z, Till K. Physical qualities of international female rugby league players by playing position. J Strength Cond Res. 2016;30(5):1333–40.
44. Wilkinson M, Cooke M, Murray S, Thompson KG, Gibson ASC, Winter EM. Physiological correlates of multiple-sprint ability and performance in international-standard squash players. J Strength Cond Res. 2012;26(2):540–7.
45. Healy R, Kenny IC, Harrison AJ. Reactive strength index: a poor indicator of reactive strength? Int J Sports Physiol Perform. 2018;13(6):802–9.
46. Barr MJ, Nolte VW. The importance of maximal leg strength for female athletes when performing drop jumps. J Strength Cond Res. 2014;28(2):373–80.
47. 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 Fit. 2013;53(2):105–11.

48. Page MJ, Moher D, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, Shamseer L, Tetzlaff JM, Akl EA, Brennan SE, Chou R. PRISMA 2020 explanation and elaboration: updated guidance and exemplars for reporting systematic reviews. BMJ. 2021;372:n160. https://doi.org/10.1136/bmj.n160.
49. Moir GL. Three different methods of calculating vertical jump height from force platform data in men and women. Meas Phys Educ Exerc Sci. 2008;12(4):207–18.
50. Healy R, Kenny IC, Harrison AJ. Assessing reactive strength measures in jumping and hopping using the OptojumpTM system. J Hum Kinet. 2016;54(1):23–32.
51. Downs SH, Black N. The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. J Epidemiol Community Health. 1998;52(6):377–84.
52. Fox AS, Bonacci J, McLean SG, Spittle M, Saunders N. What is normal? Female lower limb kinematic profiles during athletic tasks used to examine anterior cruciate ligament injury risk: a systematic review. Sports Med. 2014;44(6):815–32.
53. Bujalance-Moreno P, Latorre-Roman PA, Garcia-Pinillos F. A systematic review on small-sided games in football players: acute and chronic adaptations. J Sports Sci. 2019;37(8):921–49.
54. Fox JL, Stanton R, Sargent C, Wintour SA, Scanlan AT. The association between training load and performance in team sports: a systematic review. Sports Med. 2018;48(12):2743–74.
55. Saltin B. Limiting factors of physical performance (oxygen transport by the circulatory system during exercise in man), pp. 235–252, 1973.
56. Mero A, Komi PV, Gregor RJ. Biomechanics of sprint running. Sports Med. 1992;13(6):376–92.
57. Sheppard JM, Young WB. Agility literature review: classifications, training and testing. J Sports Sci. 2006;24(9):919–32.
58. Cumming G. Understanding the new statistics: effect sizes, confidence intervals, and meta-analysis. Routledge; 2013.
59. Cohen J. Statistical power analysis for the behavioral sciences. 2nd ed. Hillside: Lawrence Erlbaum Associates; 1988.
60. Higgins JP, Thompson SG. Quantifying heterogeneity in a meta-analysis. Stat Med. 2002;21(11):1539–58.
61. Higgins JP, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. BMJ. 2003;327(7414):557–60.
62. Higgins JP, Thompson SG, Spiegelhalter DJ. A re-evaluation of random-effects meta-analysis. J R Stat Soc A Stat Soc. 2009;172(1):137–59.
63. Sterne JA, Sutton AJ, Ioannidis JP, Terrin N, Jones DR, Lau J, Higgins JP, et al. Recommendations for examining and interpreting funnel plot asymmetry in meta-analyses of randomised controlled trials. BMJ. 2011;343:d4002.
64. Egger M, Smith GD, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. BMJ. 1997;315(7109):629–34.
65. Duval S, Tweedie R. Trim and fill: a simple funnel-plot-based method of testing and adjusting for publication bias in meta-analysis. Biometrics. 2000;56(2):455–63.
66. Suchomel TJ, Nimphius S, Stone MH. The importance of muscular strength in athletic performance. Sports Med. 2016;46(10):1419–49.
67. Suchomel TJ, Nimphius S, Bellon CR, Stone MH. The importance of muscular strength: training considerations. Sports Med. 2018;48(4):765–85.
68. Suchomel TJ, Nimphius S, Bellon CR, Hornsby WG, Stone MH. Training for muscular strength: methods for monitoring and adjusting training intensity. Sports Med. 2021;51:2051–66.
69. Jimenez-Reyes P, Samozino P, Garcia-Ramos A, Cuadrado-Penafiel V, Brughelli M, Morin JB. Relationship between vertical and horizontal force-velocity-power profiles in various sports and levels of practice. PeerJ. 2018;6:e5937.
70. Morin JB, Edouard P, Samozino P. Technical ability of force application as a determinant factor of sprint performance. Med Sci Sports Exerc. 2011;43(9):1680–8.
71. Alkjaer T, Meyland J, Raffalt PC, Lundbye-Jensen J, Simonsen EB. Neuromuscular adaptations to 4 weeks of intensive drop jump training in well-trained athletes. Physiol Rep. 2013;1(5):e00099. https://doi.org/10.1002/phy2.99.
72. Sale DG. Neural adaptation to resistance training. Med Sci Sports Exerc. 1988;20(5):S135–45.

73. Vogt M, Hoppeler HH. Eccentric exercise: mechanisms and effects when used as training regime or training adjunct. J Appl Physiol. 2014;116:1446–54.
74. Lindstedt SL, LaStayo PC, Reich TE. When active muscles lengthen: properties and consequences of eccentric contractions. Physiology. 2001;16(6):256–61.
75. Li F, Newton RU, Shi Y, Sutton D, Ding H. Correlation of eccentric strength, reactive strength, and leg stiffness with running economy in well-trained distance runners. J Strength Cond Res. 2021;35(6):1491–9.
76. Anderson T. Biomechanics and running economy. Sports Med. 1996;22(2):76–89.
77. Saunders PU, Telford RD, Pyne DB, Peltola EM, Cunningham RB, Gore CJ, Hawley JA. Short-term plyometric training improves running economy in highly trained middle and long distance runners. J Strength Cond Res. 2006;20(4):947.
78. Suarez DG, Wagle JP, Cunanan AJ, Sausaman RW, Stone MH. Dynamic correspondence of resistance training to sport: a brief review. Strength Cond J. 2019;41(4):80–8.
79. Young WB. Transfer of strength and power training to sports performance. Int J Sports Physiol Perform. 2006;1(2):74–83.
80. Hunter JP, Marshall RN, McNair PJ. Relationships between ground reaction force impulse and kinematics of sprint-running acceleration. J Appl Biomech. 2005;21(1):31–43.
81. Brughelli M, Cronin J, Levin G, Chaouachi A. Understanding change of direction ability in sport. Sports Med. 2008;38(12):1045–63.
82. Green HJ, Roy B, Grant S, Hughson R, Burnett M, Otto C, Johnson M, et al. Increases in submaximal cycling efficiency mediated by altitude acclimatization. J Appl Physiol. 2000;89(3):1189–97.
83. Young WB, James R, Montgomery I. Is muscle power related to running speed with changes of direction? J Sports Med Phys Fit. 2002;42(3):282–8.
84. Card NA. Applied meta-analysis for social science research. New York: Guilford Press; 2011.
85. Schuster D, Jones PA. Relationships between unilateral horizontal and vertical drop jumps and 20 m sprint performance. Phys Ther Sport. 2016;21:20–5.
86. Ball NB, Zanetti S. Relationship between reactive strength variables in horizontal and vertical drop jumps. J Strength Cond Res. 2012;26(5):1407–12.
87. Holm DJ, Stalbom M, Keogh JWL, Cronin J. Relationship between the kinetics and kinematics of a unilateral horizontal drop jump to sprint performance. J Strength Cond Res. 2008;22(5):1589–96.
88. McCurdy KW, Walker JL, Langford GA, Kutz MR, Guerrero JM, Mcmillan J. The relationship between kinematic determinants of jump and sprint performance in division I women soccer players. J Strength Cond Res. 2010;24(12):3200–8.
89. Barr M, Nolte V. Which measure of drop jump performance best predicts sprinting speed? J Strength Cond Res. 2011;25(7):1976–82.
90. Birchmeier T, Lisee C, Geers B, Kuenze C. Reactive strength index and knee extension strength characteristics are predictive of single-leg hop performance after anterior cruciate ligament reconstruction. J Strength Cond Res. 2019;33(5):1201–7.
91. Carr C, McMahon JJ, Comfort P. Relationships between jump and sprint performance in first-class county cricketers. J Trainol. 2015;4(1):1–5.
92. Delaney JA, Scott TJ, Ballard DA, Duthie GM, Hickmans JA, Lockie RG, Dascombe BJ. Contributing factors to change-of-direction ability in professional rugby league players. J Strength Cond Res. 2015;29(10):2688–96.
93. Lockie RG, Schultz AB, Callaghan SJ, Jeffriess MD, Luczo TM. Contribution of leg power to multidirectional speed in field sport athletes. J Aust Strength Cond. 2014;22(2):16–24.
94. Maloney SJ, Richards J, Nixon DG, Harvey LJ, Fletcher IM. Do stiffness and asymmetries predict change of direction performance? J Sports Sci. 2017;35(6):547–56.
95. Nagahara R, Naito H, Miyashiro K, Morin J, Zushi K. Traditional and ankle-specific vertical jumps as strength-power indicators for maximal sprint acceleration. J Sports Med Phys Fit. 2014;54(6):691–9.
96. Northeast J, Russell M, Shearer D, Cook CJ, Kilduff LP. Predictors of linear and multidirectional acceleration in elite soccer players. J Strength Cond Res. 2019;33(2):514–22.

97. Pehar M, Sisic N, Sekulic D, Coh M, Uljevic O, Spasic M, Krolo A, Idrizovic K. Analyzing the relationship between anthropometric and motor indices with basketball specific pre-planned and non-planned agility performances. J Sports Med Phys Fit. 2018;58(7–8):1037–44.
98. Smirniotou A, Katsikas C, Paradisis G, Argeitaki P, Zacharogiannis E, Tziortzis S. Strength-power parameters as predictors of sprinting performance. J Sports Med Phys Fitness. 2008;48(4):447.
99. Tsolakis C, Kostaki E, Vagenas G. Anthropometric, flexibility, strength-power, and sport-specific correlates in elite fencing. Percept Mot Skills. 2010;110(3C):1015–28.
100. Turner AN, Marshall G, Phillips J, Noto A, Buttigieg C, Chavda S, Downing W, Atlay N, Dimitriou L, Kilduff L. Physical characteristics underpinning repetitive lunging in fencing. J Strength Cond Res. 2016;30(11):3134–9.
101. Young WB, Miller IR, Talpey SW. Physical qualities predict change-of-direction speed but not defensive agility in Australian rules football. J Strength Cond Res. 2015;29(1):206–12.