©Journal of Sports Science and Medicine (2026) 25, 772-806
http://www.jssm.org DOI: https://doi.org/10.52082/jssm.2026.772

Review article

Hop Test Performance is Associated with Return-to-Sport but Shows Limited Association with Reinjury after Anterior Cruciate Ligament Reconstruction: A Systematic Review and Meta-Analysis

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Abstract

Hop tests are commonly used to assess return to sports (RTS) after anterior cruciate ligament reconstruction (ACLR), yet whether they can effectively predict successful RTS and reinjury risk remains unclear. This systematic review and meta-analysis aimed to determine the associations between hop test performance and the likelihood of RTS and reinjury following ACLR. PubMed, SPORTDiscus with Full Text, MEDLINE and Web of Science were searched for studies that included participants with primary unilateral ACLR, assessed functional performance using hop tests and reported outcomes of RTS and reinjury. Data on participant characteristics, follow-up duration, RTS criteria, hop test types and measures, and relevant results were extracted. Data were synthesized using quantitative or qualitative approaches. Risk of bias was assessed using a modified Newcastle-Ottawa Scale, and the quality of evidence was evaluated with the modified GRADE framework. Forty-three studies involving 17, 350 participants were included. Twenty-four studies investigated RTS and 21 examined reinjury. Meta-analyses revealed achieving a limb symmetry index (LSI) ≥ 90% in single-leg hop for distance (SLHD) (OR = 1.20, 95% CI: 1.09 to 1.33) or triple crossover hop for distance (TCHD) (OR = 1.18, 95% CI: 1.02 to 1.36) was associated with a higher probability of RTS, whereas achieving LSI ≥ 90% in triple hop for distance (OR = 1.05, 95% CI: 1.01 to 1.09) was associated with increased odds of reinjury. Subgroup analyses showed stronger associations for RTS in studies with > 90% hamstring tendon autografts (OR = 1.64, 95% CI: 1.13 to 2.39) and among individuals without meniscal injury (OR = 1.39, 95% CI: 1.14 to 1.69). Overall, low certainty of evidence suggests achieving an LSI ≥ 90% in SLHD and TCHD is associated with a higher likelihood of RTS within two years after ACLR, particularly in individuals with hamstring autografts and without meniscal injury. However, distance-based performance of hop test alone may be insufficient to predict reinjury risk.

Key words: Knee joint, ligamentous injuries, functional performance, return to play, secondary ACL injury.

Introduction

Anterior cruciate ligament (ACL) injury is one of the most common knee injuries in athletic populations (Chia et al., 2022), with an incidence of approximately 1.5 per 10, 000 athlete-exposures (Montalvo et al., 2019). For athletes aiming to return to preinjury level of sports, ACL reconstruction (ACLR) is commonly considered as the first-line treatment option (Feucht et al., 2016; Paudel et al., 2023). However, current evidence indicates that approximately 20% of patients are unable to resume their preinjury level of sports and 45% cannot return to competitive sports after ACLR (Connors et al., 2025). Additionally, the risk of reinjury during the return to sports (RTS) period remains substantial, with rates as high as 12 - 19% (Liu et al., 2026). These suboptimal outcomes may be influenced by multiple factors; however, the marked heterogeneity in existing RTS evaluation frameworks highlights the need to improve RTS criteria as a potential strategy to enhance postoperative recovery and reduce reinjury risk.

Determining an athlete's readiness for RTS is a complex, multifactorial clinical decision (Turk et al., 2023). Existing RTS criteria commonly include postoperative time, patient-reported outcome measures, isometric and isokinetic assessments of quadriceps and hamstring strength, hop tests, and evaluations of psychological readiness (Turk et al., 2023; Wright et al., 2025). Although no universal consensus has been established, functional performance assessments are considered both valid and reliable in guiding RTS decisions (Aguero et al., 2024; Glattke et al., 2023). A systematic review of post-ACLR assessment strategies demonstrated that functional performance testing is the most frequently implemented criterion (98.4% implementation rate), with hop tests being the most widely used functional testing modalities (Roe et al., 2022).

As the most commonly used assessment, hop testing has been recognized as a reliable evaluation tool to estimate functional recovery following knee injuries (Andrade et al., 2020; Berg et al., 2022). It can provide both quantitative measures (e.g., hopping distance and symmetry index) and qualitative movement descriptors (e.g., motor control patterns and biomechanics) to guide rehabilitation progression (Davies et al., 2020; Kumar et al., 2025) and inform RTS decision-making (Aguero et al., 2024). Nevertheless, evidence regarding the associations between hop test performance and successful RTS as well as a secondary ACL injury remains limited and inconclusive (Ash-

Received: 06 April 2026 / Accepted: 14 August 2026 / Published (online): 01 September 2026

igbi et al., 2020; Cronström et al., 2023). These inconsistent findings may be attributed to the variability in hop test protocols, with systematic reviews identifying more than 15 different testing approaches reported in the literature (Burgi et al., 2019; Roe et al., 2022). Accordingly, selecting a hop test protocol that can effectively differentiate patients who can successfully and safely RTS after ACLR is crucial for enhancing the screening capacity of clinical RTS criteria.

Therefore, the primary purpose of this systematic review was to evaluate whether hop test performance is associated with successful RTS following ACLR. The secondary purpose was to determine whether hop test performance is effective at identifying reinjury occurrences after ACLR.

Methods

This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page et al., 2021) and was registered prospectively with PROSPERO (CRD42025638911) on 29 January 2025.

Eligibility criteria

Studies were included if they met the following criteria: (1) recruited participants who had undergone primary and unilateral ACLR surgery, with no restrictions on age, surgical techniques or graft type; (2) applied at least one hop test (quantitative measure) to assess functional performance. Hop testing was defined as a functional performance task in which the individual executes a countermovement to generate propulsive force, achieves a flight phase, and completes the action with a stabilized landing on one or both limbs; (3) reported outcomes on whether participants experienced RTS or sustained ACL reinjuries with no restrictions on follow-up duration. RTS in this review was defined as sport participation at the same level as before the injury, while reinjury was defined as either ipsilateral graft rupture or contralateral ACL injury, with no restrictions on assessment approaches; (4) examined the association between hop test measures and RTS or reinjuries.

Studies were excluded for the following reasons: (1) inclusion of participants with concomitant injuries other than meniscal, cartilage and medial collateral ligament (MCL) injuries, as these injuries are prevalent in individuals with ACL injuries (Christino et al., 2019; Niknam et al., 2025; Rotterud et al., 2011); (2) publication type being conference proceedings, case reports, clinical commentaries or review studies.

Search strategy and study selection

The electronic databases PubMed, MEDLINE, SPORTDiscus with Full Text, and Web of Science were systematically searched from inception to 28 February 2026. The search strategy combined MeSH terms and keywords including the following terms and their variations: (“anterior cruciate ligament” OR ACL) AND (reconstruction OR surgery OR operation) AND (“return to play” OR “return to sport” OR “return to activity” OR “return to performance” OR RTS OR RTP) AND (hop OR jump OR land) (Supplementary Table 1). After removing duplicates, titles and abstracts were screened against the inclusion criteria by two independent reviewers (Y.Y.L. and Y.X.S.), followed by independent full-text assessments using the same criteria. Any discrepancies were resolved through discussion and consultation with the corresponding author (J.H.Q.).

Quality Assessment

Two authors (Y.Y.L. and Y.X.S.) independently evaluated the methodological quality of the included studies using a modified version of the Newcastle-Ottawa scale (West et al., 2023), which comprised ten items across four domains: participant selection, definition of exposure, comparability of cohorts and outcome assessment. Each item was rated as high or low risk of bias.

In addition, a modified Grade of Recommendations Assessments, Development and Evaluation (GRADE) framework (Montgomery et al., 2025) was used to assess the certainty of evidence for each outcome. This tool rated an initial evidence certainty as ‘high’, downgraded by 5 items (study limitations, inconsistency, imprecision, indirectness, and reporting bias) and upgraded by 2 items (pooled effect size and exposure-response gradient) (Supplementary Table 2). Reporting bias was further examined using funnel plots and Egger’s test when at least 10 studies were available for a given outcome in the meta-analysis.

Data Extraction and Synthesis

Data were extracted independently by two authors (Y.Y.L. and Y.X.S.). Extracted variables from each individual study included participant characteristics (age, sex, graft type, etc.), hop test types, hop test measures (absolute distance, limb symmetry index [LSI], etc.), RTS clinical criteria, rates and timing of RTS or reinjury, determination methods of RTS and reinjury, follow-up duration, reported associations between hop testing and RTS and/or reinjury. The LSI represents the performance of the injured limb relative to the uninjured limb, which is calculated as;

$$\textit{injured limb performance} \div \textit{contralateral limb performance} \times 100\%$$

When necessary, corresponding authors of the included studies were contacted to obtain additional information.

Meta-analyses were conducted when at least 3 sets of data for a given outcome were available for pooling (Review Manager, Version 5.3. Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2014) and when the odds ratios (ORs) with standard errors (SEs) could be calculated. The ORs were used to estimate the strength of associations between hop test performance and the probability of successful RTS or reinjury. If ORs were not reported or could not be derived from outcome frequencies, the standard mean difference in hop test performance between participants with and without successful RTS/reinjury was calculated and converted to an OR (Higgins et al., 2019). A random effect model was used to account for expected heterogeneity in graft types, outcome measures and follow-up durations.

Statistical heterogeneity was evaluated for each outcome using Cochran’s Q-test and quantified with the I^2

statistic, which represents the proportion of total variability due to heterogeneity rather than chance (Higgins et al., 2019). Unplanned subgroup analyses and meta-regression were performed to explore potential sources of heterogeneity, such as the presence versus absence of concomitant meniscal injuries.

When data were insufficient for meta-analysis, results were synthesized through Synthesis Without Meta-analysis (SWiM) (Campbell et al., 2020).

Results

Study characteristics

The initial search identified 7870 articles. After removing duplicates and sequentially screening titles, abstracts and full-texts, 43 studies were included in this systematic review (Figure 1), involving a total of 17, 350 participants with ACLR, with 38.87% being female. Of the included studies, 36 were cohort studies, five were cross-sectional studies, and one was case-control study. Thirty-five (81.4%) individual studies reported that participants engaged in at least a recreational level of sports before the ACL injury (Table 1). The majority of the participants (90.17%) received hamstring tendon (HT) autografts, while other graft types included quadriceps tendon (QT, 0.38%), bone-patellar tendon-bone (BPTB, 8.46%), allograft (0.88%) and synthetic graft (0.11%). In addition, 23.63% of participants sustained concomitant meniscal injuries and 7.79% had concomitant MCL injuries among studies reporting concomitant injuries (Table 1).

Across the included studies, 17 distinct hop tests were documented. The three most frequently utilized were the single-leg hop for distance (SLHD) (38 studies, 86.4%), triple hop for distance (THD) (19 studies, 43.2%), and triple crossover hop for distance (TCHD) (13 studies, 30.2%). A total of 7 measures of hop test performance were reported in the relevant studies, including LSI, side-to-side difference, absolute distance, hopping numbers, hopping time, hop measures normalized to height and to body mass, with LSI being the most widely applied in 39 studies (90.7%) (Table 2).

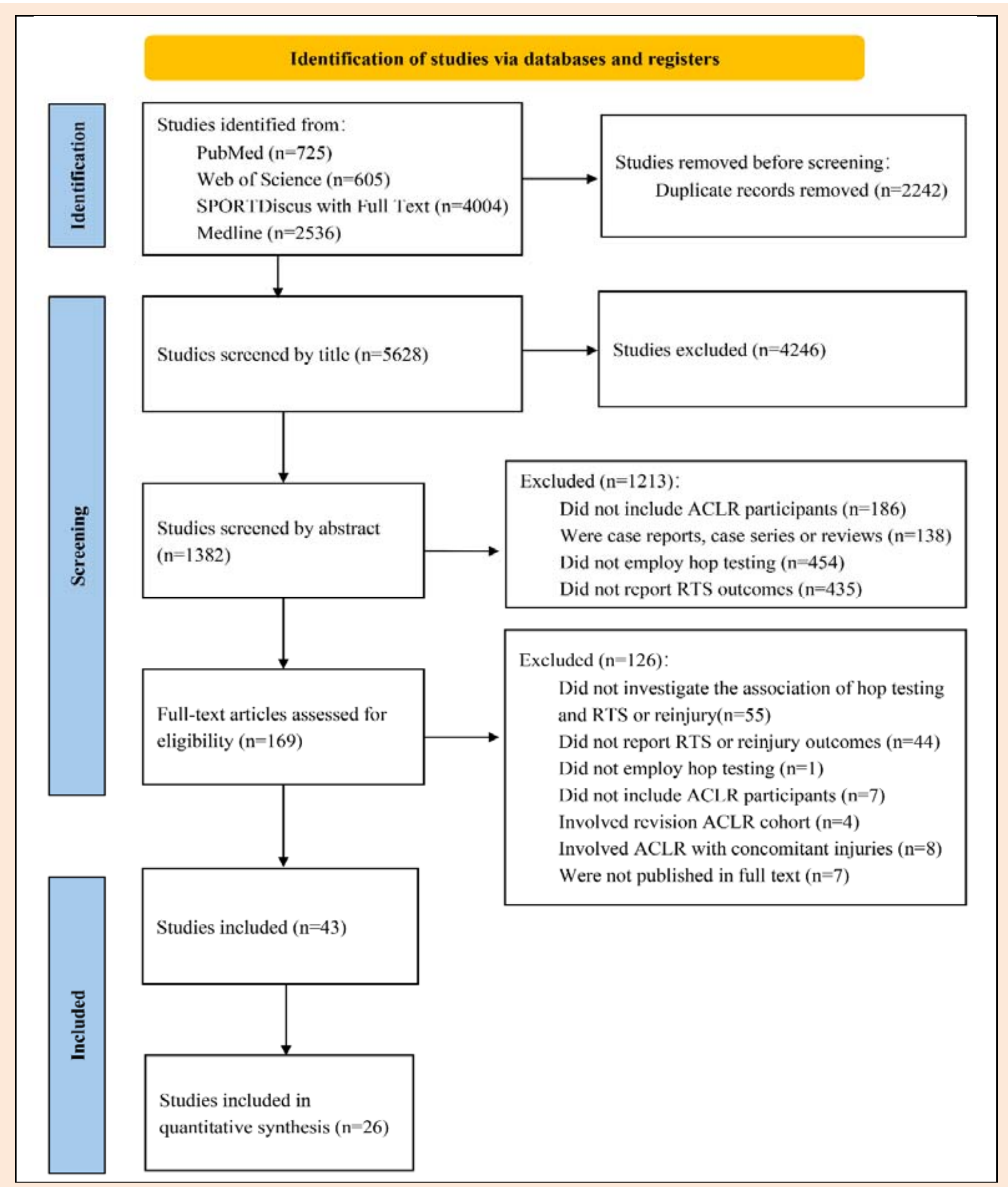

Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram of study selection.

Table 1. Study characteristics and participant demographics.

Study	Study design	Participant (female%)	Age (years)	Graft type: n	Concomitant injury: n	Preinjury sports level
Bodkin et al., 2022	cohort	192 (54.2%)	21.2 ± 9.2	BPTP: 95, HT: 58, QT: 2	NR	TAS: 8.55 ± 1.3
Cristiani et al., 2022	cohort	5393 (44.2%)	23.0 ± 9.4	BPTP: 435, HT: 4958	meniscus: 2164, cartilage: 1063	TAS: 7.5 (1 - 10)‡
Cristiani et al., 2025	cohort	1888 (10.4%)	< 20	HT: 1888	meniscus: 290, MCL: 50	NR
Faleide et al., 2021	cohort	103 (46.6%)	28.7 ± 10	BPTP: 62, HT: 41	meniscus: 43, cartilage: 1	level I or level II
Fältström et al., 2023	cohort	117 (100%)	20 ± 2	BPTP: 3, HT: 114	meniscus: 49	active football players
Figueroa et al., 2025	cohort	95 (28.4%)	23 (20 - 31)‡	BPTP: 24, HT: 62, Allograft: 9	NR	NR
Girdwood et al., 2024	cohort	124 (34.7%)	30.8 ± 8.7	HT: 124	meniscus and cartilage: 62	NR
Grindem et al., 2016	cohort	100 (54.0%)	24.3 ± 7.3	HT: 67, BPTP: 33	meniscus: 26, MCL: 30	level I or II
Ithurburn et al., 2019	cohort	98 (73.5%)	17.4 ± 2.5	BPTP: 43, HT: 49	meniscus: 49	TAS: 8.9 ± 0.7
Jang et al., 2014	cohort	67 (0.0%)	21.9 ± 3.9	HT: 67	meniscus: 27	TAS: ≥ 5
Kew et al., 2022	cohort	100 (60.0%)	16.1 ± 1.4	BPTP: 66, HT: 34	NR	NR
Kim et al., 2022	cohort	85 (45.9%)	29.2 ± 12.2	BPTP: 10, HT: 75	meniscus: 37	TAS: 6.5
King et al., 2021	case-control	115 (0.0%)	21.6 ± 4.1	BPTP: 94, HT: 21	NR	level I
Kitaguchi et al., 2020	cohort	124 (59.7%)	17.0 ± 2.7	BPTP: 38, HT: 86	meniscus: 66, cartilage: 11	TAS: 9 (8 - 9)‡
Kyritsis et al., 2016	cohort	158 (0.0%)	21.8 ± 4.9	BPTP: 50, HT: 108	NR	professional athletes
Legnani et al., 2024	cohort	33 (6.1%)	34 ± 11.5	HT: 33	meniscus: 14	TAS: 4.4 ± 2.3
Marigi et al., 2023	cohort	344 (45.6%)	26 (11 - 59)‡	Autograft: 298, Allograft: 46	NR	NR
Marty-Diloy et al., 2025	cohort	488 (37.3%)	27.6 ± 10.9	HT: 488	meniscus: 301	TAS: 7.1 ± 0.9
Moksnes et al., 2009	cohort	50 (100%)	25.9 ± 8.2	BPTP: 10, HT: 40	meniscus: 27, cartilage: 6	level I or II
Müller et al., 2015	cohort	39 (46.2%)	31.7 ± 10.32	HT: 39	0	level I or level II
Nawasreh et al., 2018	cohort	95 (33.7%)	27.6 ± 10.5	Autograft: 36, Allograft: 59	0	level I or II
Niederer et al., 2024	cohort	88 (47.7%)	25 ± 5	BPTP: 88	NR	TAS: 5.7
Niederer et al., 2025	cohort	138 (41.3%)	25.6 ± 5.1	HT: 124, QT: 14	NR	TAS: 3 - 10
Novaretti et al., 2018	cohort	58 (19.0%)	34.5 ± 11.3	NR	NR	TAS: ≥ 5
Nyland et al., 2025	cohort	204 (47.1%)	19.7 ± 6	NR	NR	NR
Ohji et al., 2024	cross-sectional	65 (46.2%)	21.0 (5.0)§	HT: 65	meniscus: 51	TAS: 7.8 ± 1.2
Ohji et al., 2021a	cross-sectional	44 (43.2%)	23.0 (13.0)§	BPTP: 4, HT: 40	meniscus: 32	TAS: 8.0 (2.0)§
Ohji et al., 2021b	cross-sectional	73 (42.5%)	21.0 (6.0)§	BPTP: 6, HT: 67	meniscus: 54	TAS: 7.8 ± 1.2
Paterno et al., 2022	cohort	159 (70.4%)	17.2 ± 2.6	BPTP: 59, HT: 86, Allograft: 14	meniscus: 84	level I or II
Paterno et al., 2025	cohort	51 (64.7%)	15.6 ± 2.2	HT: 42, BPTP: 9	NR	level I or II
Piussi et al., 2023	cohort	419 (48.9%)	23.9 ± 7.5	BPTP: 53, HT: 331, Others: 5	0	TAS: 8.43
Senorski et al., 2017	cohort	157 (49.0%)	22.4 ± 4.0	NR	NR	TAS: ≥ 6
Simonsson et al., 2024	cohort	233 (51.1%)	20.5 ± 4.0	HT: 184, BPTP: 44, Other: 5	NR	TAS ≥ 6
Toole et al., 2017	cohort	115 (23.5%)	17.1 ± 2.5	BPTP:50, HT: 57, Allograft: 8	NR	TAS: 8.34 ± 1.54
Ueda et al., 2022	cross-sectional	144 (43.1%)	25.8 ± 11.9	BPTP: 6, HT: 138	meniscus: 104, cartilage: 8	TAS: 7.6 ± 1.4
van Melick et al., 2022	cohort	175 (29.7%)	24 ± 6	HT: 123	meniscus: 80, cartilage: 46	TAS: 8.1 ± 1.0
Webster et al., 2017	cohort	2570 (35.3%)	28.1 ± 10	HT: 2570	NR	level I or II
Webster et al., 2018	cross-sectional	1440 (31.1%)	26 (12 - 55)‡	BPTP: 8, HT: 1414, Synthetic graft: 18	NR	Cincinnati Sports Activity Scale ≥ 85
Webster et al., 2019a	cohort	329 (39.2%)	17.2 ± 2	HT: 323	meniscus: 186, cartilage: 35	NR
Webster et al., 2019b	cohort	222 (40.5%)	25.8 ± 9.0	BPTP: 4, HT: 218	NR	Marx activity level: 13 (6 - 16)‡
Webster et al., 2020	cohort	450 (39.1%)	24 ± 7	BPTP: 12, HT: 391, QT: 47	meniscus: 272, cartilage: 101	level I
Welling et al., 2020	cohort	64 (31.3%)	22.8 ± 8.7	BPTP: 19, HT: 45	NR	competitive, pivoting sports
Zsidai et al., 2026	cohort	344 (100%)	21.4 ± 4.9	HT: 249, BPTP: 65, Allograft: 2	meniscus: 143	TAS: 6 - 10

NR: not reported; HT: hamstring tendon autograft; BPTB: bone-patellar tendon-bone autograft; QT: quadriceps tendon autograft; TAS: Tegner Activity Scale; IKDC: International Knee Documentation Committee. ‡ median (95% confidence interval); § median (interquartile range).

Table 2. **Hop test characteristics and outcome assessment.**

Study	Time of testing (month)†	Hop test(s)	Measure(s) of hop test	Follow-up period (year)†
Bodkin et al., 2022	6.73 ± 1.4	SLHD, THD, 6-mTH	LSI, normalized distance, hopping time	> 2
Cristiani et al., 2022	6	SLHD	LSI	5
Cristiani et al., 2025	6	SLHD	LSI	5
Faleide et al., 2021	10.4 ± 1.3	Battery (SLHD, THD, TCHD, 6-mTH)	LSI	2.1 ± 0.2
Fältström et al., 2023	19 ± 9	SLHD, side hop, 5-jump	LSI, absolute and normalized distance, hopping numbers	3.7 ± 0.7
Figueroa et al., 2025	11 (8.6 - 13.7)‡	THD	LSI	2
Girdwood et al., 2024	12	SLHD, side hop	LSI	11 after testing
Grindem et al., 2016	6 - 12	SLHD, THD, TCHD, 6-mTH	LSI	2
Ithurburn et al., 2019	1 after RTS	SLHD, THD, TCHD	LSI, normalized distance	1 after RTS
Jang et al., 2014	24	SLHD	absolute distance	2.9 (2.0 - 3.8)‡
Kew et al., 2022	6.7 ± 1.6	SLHD, THD, TCHD, 6-mTH	LSI	4.0 ± 1.2
Kim et al., 2022	24	SLHD	side-to-side difference	2
King et al., 2021	9.0 ± 3.1	SLHD, SLCJ, SLDVJ	LSI, absolute distance/ length	2
Kitaguchi et al., 2020	6	SLHD	LSI	1
Kyritsis et al., 2016	6 after RTS	SLHD, THD, TCHD	LSI	2.1 (0.5 - 5.8)‡ after RTS
Legnani et al., 2024	12	bipedal countermovement jump, side hop	LSI	1
Marigi et al., 2023	6.1 ± 0.5	SLHD, THD, SLVJ	LSI	6.8 (2 - 17.9)‡
Marty-Diloy et al., 2025	6	SLHD, THD, side hop, drop jump	absolute distance	4.9 ± 1.23
Moksnes et al., 2009	2.7 ± 1.2	SLHD, THD, TCHD, 6-mTH	LSI	1.1 ± 0.1 after testing
Müller et al., 2015	6.2 ± 0.3	SLHD, THD, TCHD	LSI	0.6
Nawasreh et al., 2018	6	SLHD, THD, TCHD, 6-mTH	LSI	2.1 ± 0.4
Niederer et al., 2024	7.5	LSHD, BDVJ, balance front hop, balance side hop	LSI	0.6 ± 0.2
Niederer et al., 2025	6 - 9	balance side hop	point	2
Novaretti et al., 2018	6	BDVJ	LSI	2.1 (1.0 - 4.4)‡
Nyland et al., 2025	8.5 ± 2.4	THD, 20-meter timed hop and crossover hop	LSI, hopping time	7.8 ± 4
Ohji et al., 2024	13.5 (13.0)§	SLHD, SLVJ, SLDVJ	LSI	1.1 (1.1)§
Ohji et al., 2021a	23.5 (21.0)§	SLHD	LSI	2.0 (1.8)§
Ohji et al., 2021b	13.5 (13.0)§	SLHD	LSI	1.1 (1.1)§
Paterno et al., 2022	1 after RTS	SLHD, THD, SLVJ	height-normalized distance/ length	2
Paterno et al., 2025	8.4 ± 1.6	SLHD, THD, TCHD, 6-mTH	LSI	3 after testing
Piussi et al., 2023	NR	Battery (SLVJ, SLHD)	LSI	2
Senorski et al., 2017	NR	SLHD, SLVJ, side hop	normalized distance /length /hopping numbers	0.9 ± 0.3
Simonsson et al., 2024	4	SLHD, side hop, SLVJ	LSI	2 after RTS
Toole et al., 2017	8.2 ± 2.4	SLHD, THD, TCHD, 6-mTH	LSI	1 after RTS
Ueda et al., 2022	12	SLHD	LSI	12
van Melick et al., 2022	NR	Battery (SLVJ, SLHD, side hop)	LSI	2
Webster et al., 2017	NR	SLHD, TCHD	LSI	1.2 (1 - 1.7)‡
Webster et al., 2018	13.1 ± 2.6	SLHD	LSI	1
Webster et al., 2019a	12	SLHD, TCHD	LSI	5 (3 - 9)‡
Webster et al., 2019b	12	Battery (SLHD, TCHD)	LSI	> 2
Webster et al., 2020	6.5 ± 0.6	SLHD, THD	LSI	1
Welling et al., 2020	10.1 ± 1.0	SLHD, THD, side hop	LSI, hopping distance and numbers	2.1 ± 0.8
Zsidai et al., 2026	12	SLHD, SLVJ, side hop	LSI	2

NR: not reported; LSI: limb symmetry index; SLHD: single-leg hop for distance; THD: triple hop for distance; TCHD: triple crossover hop for distance; 6-mTH: 6-meter timed hop; SLCJ: single-leg countermovement jump; SLVJ: single-leg vertical jump; BDVJ: bipedal drop vertical jump; SLDVJ: single-leg drop vertical jump. † postoperative duration unless otherwise noted.; ‡ median (95% confidence interval); § median (interquartile range)

Hop performance data were collected between 6 and 24 months postoperatively, whereas follow-up for RTS/ reinjury spanned 7 months to 11 years post-ACLR. Beyond hop tests, the assessment modalities in RTS criteria across the individual studies demonstrated homogeneity. Specifically, 38 studies (88.3%) consistently assessed patient-reported outcomes and 33 (76.7%) tested maximal knee-extensor or -flexor strength (Supplementary Table 3).

Twenty-four studies (Bodkin et al., 2022; Faleide et al., 2021; Ithurburn et al., 2019; Jang et al., 2014; Kim et al., 2022; Kitaguchi et al., 2020; Legnani et al., 2024; Moksnes and Risberg, 2009; Müller et al., 2015; Nawasreh et al., 2018; Niederer et al., 2025; Niederer et al., 2024; Novaretti et al., 2018; Ohji et al., 2024; Ohji et al., 2021a; Ohji et al., 2021b; Senorski et al., 2017; Toole et al., 2017; Ueda et al., 2022; Webster and Feller, 2017; Webster and Feller, 2018; Webster and Feller, 2020; Webster et al., 2019; Welling et al., 2020) investigated the association between hop testing and RTS, and 21 (Bodkin et al., 2022; Cristiani et al., 2022; Cristiani et al., 2025; Fältström et al., 2023; Figueroa Poblete et al., 2025; Girdwood et al., 2024; Grindem et al., 2016; Ithurburn et al., 2019; Kew et al., 2022; King et al., 2021; Kyritsis et al., 2016; Marigi et al., 2023; Marty-Diloy et al., 2025; Nyland et al., 2025; Paterno et al., 2025; Paterno et al., 2022; Piussi et al., 2023; Simonsson et al., 2024; Van Melick et al., 2022; Webster and Feller, 2019; Zsidai et al., 2026) examined reinjury outcomes. RTS status was determined by self-report in 12 studies (50.0%) and by quantitative score in 12 studies (50.0%). Reinjury was by self-report in 7 studies (33.3%) and via MRI or medical records in 8 studies (38.1%) (Supplementary Table 3).

Risk of bias

Among all the included studies, only 4 (9.3%) conducted power analysis. Sixteen studies (37.2%) had a dropout rate > 15% during follow-up (mean dropout rate across all included studies was 10.03%), and 24 (55.8%) did not control for potential confounders (e.g., age, sex, preinjury sports level) in the statistical analysis (Supplementary Table 4).

Associations between hop test performance and return to sports

A total of 24 studies (Bodkin et al., 2022; Faleide et al., 2021; Ithurburn et al., 2019; Jang et al., 2014; Kim et al., 2022; Kitaguchi et al., 2020; Legnani et al., 2024; Moksnes and Risberg, 2009; Müller et al., 2015; Nawasreh et al., 2018; Niederer et al., 2025; Niederer et al., 2024; Novaretti et al., 2018; Ohji et al., 2024; Ohji et al., 2021a; Ohji et al., 2021b; Senorski et al., 2017; Toole et al., 2017; Ueda et al., 2022; Webster and Feller, 2017; Webster and Feller, 2018; Webster and Feller, 2020; Webster et al., 2019; Welling et al., 2020) investigated the association between hop test performance and the success of RTS following ACLR, reporting 13 different types of hop tests. In the relevant studies, the performance of hop tests was typically assessed within 6 to 24 months postoperatively, with subsequent RTS evaluation occurring from 7 to 34.4 months post-ACLR (Table 2).

Single-leg hop for distance (SLHD)

Nineteen studies (Bodkin et al., 2022; Ithurburn et al., 2019; Jang et al., 2014; Kim et al., 2022; Kitaguchi et al., 2020; Moksnes and Risberg, 2009; Müller et al., 2015; Nawasreh et al., 2018; Niederer et al., 2024; Ohji et al., 2024; Ohji et al., 2021a; Ohji et al., 2021b; Senorski et al., 2017; Toole et al., 2017; Ueda et al., 2022; Webster and Feller, 2017; Webster and Feller, 2018; Webster and Feller, 2020; Welling et al., 2020) (79.2%) employed the SLHD to evaluate participants' functional performance. Different outcome measures were used to quantify the performance across studies, including LSI (n = 16), absolute distance (n = 2), side-to-side difference (n = 1) and distance normalized to height or body mass (n = 4) (Table 2). A meta-analysis of 15 studies (Bodkin et al., 2022; Kitaguchi et al., 2020; Moksnes and Risberg, 2009; Müller et al., 2015; Nawasreh et al., 2018; Niederer et al., 2024; Ohji et al., 2024; Ohji et al., 2021a; Ohji et al., 2021b; Toole et al., 2017; Ueda et al., 2022; Webster and Feller, 2017; Webster and Feller, 2018; Webster and Feller, 2020; Welling et al., 2020) (5315 participants) demonstrated that achieving an LSI ≥ 90% in SLHD was significantly associated with successful RTS (OR = 1.20, 95% CI: 1.09 to 1.33, I^2 = 78%) (Figure 2), whereas one study (Ithurburn et al., 2019) with qualitative analysis reported no association (Table 3). Overall, low certainty of evidence suggests that achieving an LSI ≥ 90% on SLHD is significantly associated with the success of RTS following ACLR (Supplementary Table 5).

Regarding other quantitative measures of SLHD performance, the certainty of evidence remains inconsistent or limited. For the absolute distance of SLHD, one (Welling et al., 2020) demonstrated that greater distance on both involved and uninvolved limbs significantly correlated with RTS, while the other (Jang et al., 2014) showed no association. For height-normalized SLHD distance, two (Ithurburn et al., 2019; Ohji et al., 2021b) of three studies revealed that better performance on the involved limb was associated with successful RTS, while the third (Bodkin et al., 2022) found no association; only one (Ithurburn et al., 2019) examined the performance of uninvolved limb and found no association. No association results were also reported by one study (Senorski et al., 2017) which examined body-mass-normalized distance on both involved and uninvolved limbs. Only one study (Kim et al., 2022) measured SLHD performance by side-to-side difference and found a significant association (Table 3, Supplementary Table 5).

Triple hop for distance (THD)

Seven studies (Bodkin et al., 2022; Ithurburn et al., 2019; Moksnes and Risberg, 2009; Müller et al., 2015; Nawasreh et al., 2018; Toole et al., 2017; Welling et al., 2020) (29.2%) examined the association between THD performance and RTS, using different outcome measures: LSI (n = 7), absolute distance (n = 1) and distance normalized to height (n = 2) (Table 2). A meta-analysis of 6 studies (Bodkin et al., 2022; Moksnes and Risberg, 2009; Müller et al., 2015; Nawasreh et al., 2018; Toole et al., 2017; Welling et al., 2020) (520 participants) demonstrated no association between achieving an LSI ≥ 90% and successful RTS (OR

= 1.07, 95% CI: 0.99 to 1.16, I^2 = 71%) (Figure 2), which was consistent with the findings of an additional study (Ithurburn et al., 2019) included in qualitative synthesis (Table 3). Therefore, low certainty of evidence suggests that achieving an LSI ≥ 90% on THD had no association with successful RTS following ACLR (Supplementary Table 5).

Among studies that did not measure LSI, one study (Welling et al., 2020) reported that a greater absolute distance on both involved and uninvolved limbs in THD was associated with a higher probability of RTS. Two additional studies (Bodkin et al., 2022; Ithurburn et al., 2019) yielded inconsistent findings regarding the association between height-normalized THD distance and successful RTS on involved and uninvolved limbs. Specifically, Ithurburn et al. (2019) found a significant association on both involved and uninvolved limbs, whereas Bodkin et al. (2022) reported no association on involved limb (Table 3). Overall, the available evidence regarding absolute/normalized distance of THD and RTS following ACLR was limited and inconsistent (Supplementary Table 5).

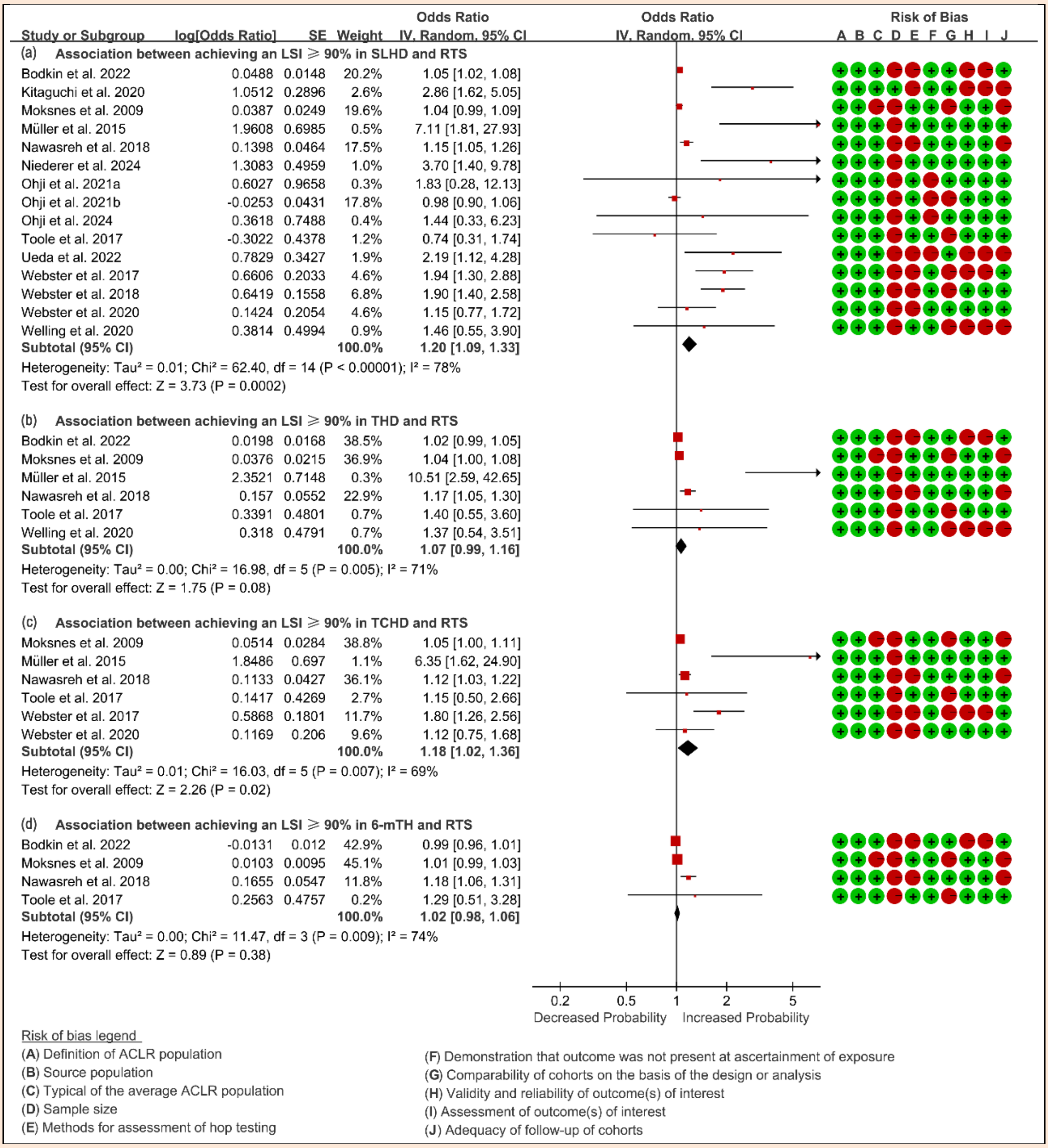

Figure 2. Forest plot displaying associations between achieving LSI (limb symmetry index) ≥ 90% in single-leg hop for distance (SLHD), triple hop for distance (THD), triple crossover hop for distance (TCHD), 6-meter timed hop (6-mTH) and RTS (return to sports), and quality assessment of each study using modified Newcastle-Ottawa Scale.

Table 3. Summary of findings from variables excluded from meta-analyses on associations between hop test measures and return to sports.

Study	Measure of hop test				
	LSI	Absolute value†	Height-normalized value†	Body-mass-normalized value†	Side-to-side difference
Single-leg hop for distance					
Bodkin et al., 2022	--	☒	IL: OR = 8.95 (0.80 - 100.5)‡; P = 0.076	☒	☒
Ithurburn et al., 2019	94.1 ± 6.4 vs. 93.8 ± 6.0; P > 0.05§	☒	IL: P = 0.043¶ UL: P = 0.133¶	☒	☒
Jang et al., 2014	☒	IL: 157.7 ± 23.6 vs. 153.9 ± 32.4; P = 0.877§ UL: 173.7 ± 19.6 vs. 173.3 ± 24.3; P = 0.959§	☒	☒	☒
Kim et al., 2022	☒	☒	☒	☒	6.8 ± 1.4 vs. 15.3 ± 6.1;P = 0.04§
Ohji et al., 2021b	--	☒	IL: 81.9 ± 13.2 vs. 73.5 ± 18.1; P = 0.025§	☒	☒
Senorski et al., 2017	☒	☒	☒	IL: 2.04 ± 0.35 vs. 1.95 ± 0.3; P > 0.05§ UL: 2.1 ± 0.36 vs. 2.05 ± 0.42; P > 0.05§	☒
Welling et al., 2020	--	IL: 163.7 ± 27.4 vs. 142.4 ± 35.6; P = 0.013§ UL: 168.8 ± 25.6 vs. 149.4 ± 29.5; P = 0.011§	☒	☒	☒
Triple hop for distance					
Bodkin et al., 2022	--	☒	IL: OR = 1.67 (0.76 - 3.64)‡; P = 0.200	☒	☒
Ithurburn et al., 2019	95.4 ± 6.3 vs. 95.1 ± 7.3; P > 0.05§	☒	IL: P = 0.007¶ UL: P = 0.004¶	☒	☒
Welling et al., 2020	--	IL: 524.8 ± 84.4 vs. 469.3 ± 91.5; P = 0.024§ UL: 538.9 ± 81.2 vs. 487.4 ± 75.2; P = 0.023§	☒	☒	☒
Triple crossover hop for distance					
Ithurburn et al., 2019	95.3 ± 7.6 vs. 93.5 ± 13.2; P > 0.05§	☒	IL: P = 0.033¶ UL: P = 0.037¶	☒	☒
6-meter timed hop					
Bodkin et al., 2022	--	IL: OR = 0.80 (0.52 - 1.24)‡; P = 0.317	☒	☒	☒
Side hop					
Legnani et al., 2024	P > 0.05¶	☒	☒	☒	☒
Senorski et al., 2017	☒	☒	☒	IL: 0.76 ± 0.16 vs. 0.6 ± 0.22; P > 0.05§ UL: 0.8 ± 0.15 vs. 0.65 ± 0.16; P > 0.05§	☒
Welling et al., 2020	98.0 ± 14.1 vs. 91.3 ± 17.1; P = 0.116§	IL: 53.3 ± 13.1 vs. 43.8 ± 17.1; P = 0.021§ UL: 54.4 ± 11.6 vs. 46.9 ± 14.0; P = 0.032§	☒	☒	☒
Balance front hop					
Niederer et al., 2024	OR = 0.8 (0.3 - 2.1)‡; P = 0.4††	☒	☒	☒	☒
Balance side hop					
Niederer et al., 2024	OR = 0.8 (0.3 - 2.3)‡; P = 0.8††	☒	☒	☒	☒
Niederer et al., 2025	☒	IL: OR = 1 (0.998, 1.002)‡, P = 0.999	☒	☒	☒
Bipedal drop vertical jump					
Niederer et al., 2024	OR = 1.4 (0.5 - 3.9)‡; P = 0.4††	☒	☒	☒	☒
Novaretti et al., 2018	71.9 ± 17.1 vs. 72.1 ± 17.7; P = 0.96§	☒	☒	☒	☒

† hopping time for 6-meter timed hop, hopping numbers for side hop, hopping length for vertical jump, hopping distance for other hop tests; ‡ median (95% confidence interval); § comparison between return-to-sports (the former) and non-return-to-sports (the latter) groups; ¶ data were presented as box plots; †† result was calculated based on achieving LSI ≥ 90% vs. <90%); Abbreviations: --: data were included in meta-analysis; ☒: not reported; LSI: limb symmetry index; OR: odds ratio; IL: involved limb; UL: uninvolved limb.

Table 3. Continue…

Study	Measure of hop test				
	LSI	Absolute value†	Height-normalized value†	Body-mass-normalized value†	Side-to-side difference
Bipodal countermovement jump					
Legnani et al., 2024	P > 0.05¶	☒	☒	☒	☒
Single-leg drop vertical jump					
Ohji et al., 2024	93.7 ± 16.4 vs. 79.8 ± 18.1; P = 0.002§	☒	☒	☒	☒
Single-leg vertical jump					
Ohji et al., 2024	92.5 ± 9.8 vs. 87.2 ± 9.3; P = 0.043§	☒	☒	☒	☒
Senorski et al., 2017	☒	☒	☒	IL:0.25 ± 0.06 vs. 0.24 ± 0.07; P > 0.05§ UL: 0.28 ± 0.05 vs. 0.27 ± 0.05; P > 0.05§	☒
Square hop					
Müller et al., 2015	87.5 ± 20.4 vs. 83.8 ± 44.6; P > 0.05§	☒	☒	☒	☒
Hop test battery					
Faleide et al., 2021	OR = 1.02 (0.97 - 1.07)‡; P = 0.425††	☒	☒	☒	☒
Nawasreh et al., 2018	P < 0.001; R2 = 0.435††	☒	☒	☒	☒
Webster et al., 2019b	OR = 1.03 (1 - 1.06)‡; P = 0.048††	☒	☒	☒	☒

† hopping time for 6-meter timed hop, hopping numbers for side hop, hopping length for vertical jump, hopping distance for other hop tests; ‡ median (95% confidence interval); § comparison between return-to-sports (the former) and non-return-to-sports (the latter) groups; ¶ data were presented as box plots; †† result was calculated based on achieving LSI ≥ 90% vs. <90%); Abbreviations: --: data were included in meta-analysis; ☒: not reported; LSI: limb symmetry index; OR: odds ratio; IL: involved limb; UL: uninvolved limb

Triple crossover hop for distance (TCHD)

Seven (Ithurburn et al., 2019; Moksnes and Risberg, 2009; Müller et al., 2015; Nawasreh et al., 2018; Toole et al., 2017; Webster and Feller, 2017; Webster and Feller, 2020) of the 24 studies (29.2%) evaluated the association between TCHD performance and RTS, using LSI (n = 7) or distance normalized to height (n = 1) (Table 2). A meta-analysis of 6 studies (Moksnes and Risberg, 2009; Müller et al., 2015; Nawasreh et al., 2018; Toole et al., 2017; Webster and Feller, 2017; Webster and Feller, 2020) (3081 participants) demonstrated that achieving an LSI ≥ 90% in TCHD was significantly associated with successful RTS (OR = 1.18, 95% CI: 1.02 to 1.36, I^2 = 69%) (Figure 2), while no association was reported by one additional study (Ithurburn et al., 2019) in the qualitative synthesis (Table 3). The above findings reached a low certainty of evidence suggests that achieving an LSI ≥ 90% in TCHD was significantly associated with successful RTS (Supplementary Table 5). Furthermore, a single study (Ithurburn et al., 2019) indicated that higher height-normalized TCHD distance on both involved and uninvolved limbs was associated with RTS (limited certainty of evidence) (Table 3, Supplement Table 5).

6-meter timed hop (6-mTH)

Four studies (Bodkin et al., 2022; Moksnes and Risberg, 2009; Nawasreh et al., 2018; Toole et al., 2017) (16.7%) examined the association between 6-mTH performance and RTS using the measures of LSI (n = 4) or hopping time (n = 1) (Table 2). A meta-analysis of 4 studies (Bodkin et al., 2022; Moksnes and Risberg, 2009; Nawasreh et al., 2018; Toole et al., 2017) (417 participants) indicated that achieving an LSI ≥ 90% in 6-mTH was not associated with successful RTS (OR = 1.02, 95% CI: 0.98 to 1.06, I^2 = 74%), which achieved a low certainty of evidence (Figure 2, Supplementary Table 5). A non-significant association was reported in a single study (Bodkin et al., 2022) that measured hopping time (limited certainty of evidence) (Table 3, Supplementary Table 5).

Other hop tests

Eight studies (Legnani et al., 2024; Müller et al., 2015; Niederer et al., 2025; Niederer et al., 2024; Novaretti et al., 2018; Ohji et al., 2024; Senorski et al., 2017; Welling et al., 2020) evaluated the association between measures of eight individual hop tests and probability of RTS, including side hop, balance front hop, drop vertical jump, single-leg vertical jump (SLVJ) and square hop, etc. (Table 2).

For side hop test, one study (Welling et al., 2020) reported that a greater hopping number on both involved and uninvolved limbs was associated with RTS. However, no significant associations were found between body mass normalized hopping numbers and RTS (Senorski et al., 2017). In addition, low certainty of evidence from two studies suggested that the LSI in side hop was not associated with RTS (Legnani et al., 2024;

Welling et al., 2020) (Table 3, Supplementary Table 5).

Regarding the LSI in SLVJ and single-leg drop vertical jump, limited evidence from one study (Ohji et al., 2024) found significant differences between RTS and non-RTS groups for both tests (Table 3, Supplementary Table 5).

Evidence for hop test batteries was inconsistent: two studies (Nawasreh et al., 2018; Webster et al., 2019) observed that meeting an LSI ≥ 90% in hop test batteries was associated with RTS, whereas one study (Faleide et al., 2021) found no association (Table 3). For the remaining hop tests, no significant associations between performance measures and successful RTS were observed, with the certainty of evidence ranging from limited to low (Table 3, Supplementary Table 5).

Associations between hop test performance and reinjury

Twenty-one studies (Bodkin et al., 2022; Cristiani et al., 2022; Cristiani et al., 2025; Fältström et al., 2023; Figueroa Poblete et al., 2025; Girdwood et al., 2024; Grindem et al., 2016; Ithurburn et al., 2019; Kew et al., 2022; King et al., 2021; Kyritsis et al., 2016; Marigi et al., 2023; Marty-Diloy et al., 2025; Nyland et al., 2025; Paterno et al., 2025; Paterno et al., 2022; Piussi et al., 2023; Simonsson et al., 2024; Van Melick et al., 2022; Webster and Feller, 2019; Zsidai et al., 2026) evaluated the association between hop test performance and the occurrence of reinjury after ACLR, reporting a total of 12 different hop tests. The hop testing was normally conducted between 6 and 19 months post-ACLR, while reinjury follow-up periods ranged from 2 to 11 years after surgery (Table 2).

Single-leg hop for distance (SLHD)

Seventeen studies (Bodkin et al., 2022; Cristiani et al., 2022; Cristiani et al., 2025; Fältström et al., 2023; Girdwood et al., 2024; Grindem et al., 2016; Ithurburn et al., 2019; Kew et al., 2022; King et al., 2021; Kyritsis et al., 2016; Marigi et al., 2023; Marty-Diloy et al., 2025; Paterno et al., 2025; Paterno et al., 2022; Simonsson et al., 2024; Webster and Feller, 2019; Zsidai et al., 2026) (81.0%) investigated the association between SLHD performance and reinjury, among which LSI (n = 16), absolute distance (n = 4) and height-normalized distance (n = 4) were used to quantify the performance (Table 2). A meta-analysis of 13 studies (Bodkin et al., 2022; Cristiani et al., 2022; Cristiani et al., 2025; Fältström et al., 2023; Grindem et al., 2016; Kew et al., 2022; King et al., 2021; Kyritsis et al., 2016; Marigi et al., 2023; Paterno et al., 2022; Simonsson et al., 2024; Webster and Feller, 2019; Zsidai et al., 2026) (9393 participants) found that achieving an LSI ≥ 90% in SLHD was not associated with odds of reinjury (OR = 1.02, 95% CI: 0.99 to 1.06, I^2 = 29%) (Figure 3), supported by two studies (Ithurburn et al., 2019; Paterno et al., 2025) excluded from this meta-analysis (Table 4). Overall, moderate certainty of evidence suggests that achieving an LSI ≥ 90% in SLHD was not associated with the risk of ACL reinjury following ACLR (Supplementary Table 5).

Furthermore, the results of another meta-analysis of 3 studies (Bodkin et al., 2022; Fältström et al., 2023; Marigi et al., 2023) involving 616 participants showed no significant association between height-normalized SLHD distance on the involved limb and reinjury (OR = 1.02, 95% CI: 0.97 to 1.06, I^2 = 68%). This finding was further supported by 2 additional studies (Girdwood et al., 2024; Ithurburn et al., 2019) included in the qualitative synthesis, providing low certainty of evidence for the absence of an association (Figure 3, Table 4). Similarly, five studies (Fältström et al., 2023; Ithurburn et al., 2019; King et al., 2021; Marigi et al., 2023; Marty-Diloy et al., 2025) consistently reported no association between SLHD performance and reinjury odds when measured by absolute or height-normalized distance (Table 4). Overall, this evidence was rated as low certainty (Supplementary Table 5).

Triple hop for distance (THD)

Ten studies (Bodkin et al., 2022; Grindem et al., 2016; Ithurburn et al., 2019; Kew et al., 2022; Kyritsis et al., 2016; Marigi et al., 2023; Marty-Diloy et al., 2025; Nyland et al., 2025; Paterno et al., 2025; Paterno et al., 2022) (47.6%) investigated the association between THD performance and reinjury, using LSI (n = 9), absolute distance (n = 2) and height-normalized distance (n = 2) as outcome measures (Table 2). A meta-analysis of 7 studies (Bodkin et al., 2022; Grindem et al., 2016; Kew et al., 2022; Kyritsis et al., 2016; Marigi et al., 2023; Nyland et al., 2025; Paterno et al., 2022) (1178 participants) indicated that achieving an LSI ≥ 90% in THD was significantly associated with increased odds of reinjury (OR = 1.05, 95% CI: 1.01 to 1.09, I^2 = 0%) (Figure 4). However, two additional studies (Ithurburn et al., 2019; Paterno et al., 2025) that were not included in the meta-analysis reported no association (Table 4). Overall, the certainty of evidence for this association was rated as moderate (Supplementary Table 5).

Two studies (Marty-Diloy et al., 2025; Nyland et al., 2025) observed no association between greater absolute distance and reinjury odds on either involved or uninvolved limbs (very low certainty of evidence). Regarding height-normalized distance, two studies (Bodkin et al., 2022; Marigi et al., 2023) found no association with reinjury, whereas one study (Ithurburn et al., 2019) reported significant associations on both involved and uninvolved limbs (inconsistent certainty of evidence) (Table 4, Supplementary Table 5).

Triple crossover hop for distance (TCHD)

Seven studies (Grindem et al., 2016; Ithurburn et al., 2019; Kew et al., 2022; Kyritsis et al., 2016; Paterno et al., 2025; Paterno et al., 2022; Webster and Feller, 2019) (33.3%) investigated the association between TCHD performance and reinjury, assessing LSI (n = 7) or distance normalized to height (n = 1) (Table 2). A meta-analysis of 5 studies (Kew et al., 2022; Kyritsis et al., 2016; Paterno et al., 2022; Webster and Feller, 2019) (804 participants) demonstrated that there was no association between achieving an LSI ≥ 90% in TCHD and reinjury occurrence (OR = 1.00, 95% CI: 0.84 to 1.20, I^2 = 16%) (Figure 4). This finding was also supported by one study (Ithurburn et al., 2019) with qualitative synthesis. Overall, low certainty of evidence suggests that there was no significant association between LSI ≥ 90% in TCHD and ACL reinjury risk.

Two studies (Paterno et al., 2025; Webster and Feller, 2019) further investigated the predictive effects of TCHD for the occurrence of subsequent ipsilateral graft ruptures and contralateral ACL injuries and found no association with either outcome, which reached a low certainty of evidence. Only one study (Ithurburn et al., 2019) reported no association between height-normalized TCHD distance and reinjury odds on either involved or uninvolved limbs (limited certainty of evidence) (Table 4, Supplementary 5).

6-meter timed hop (6-mTH)

Five studies (Bodkin et al., 2022; Grindem et al., 2016; Kew et al., 2022; Paterno et al., 2025; Paterno et al., 2022) (23.8%) examined the association between 6-mTH performance and reinjury, using LSI (n = 5) and hopping time (n = 1) as outcome measures (Table 2). A meta-analysis of these 4 studies (Bodkin et al., 2022; Grindem et al., 2016; Kew et al., 2022; Paterno et al., 2022) (472 participants) found no association between achieving an LSI ≥ 90% in 6-mTH and reinjury (OR = 1.00, 95% CI: 0.90 to 1.11, I^2 = 20%) (Figure 4). This finding was consistent with one additional study (Paterno et al., 2025). Overall, the certainty of evidence was rated as low (Supplementary Table 5). Additionally, limited evidence from a single study (Bodkin et al., 2022) evaluating hopping time (in seconds) also reported no association (Table 4, Supplementary Table 5).

Other hop tests

Nine studies (Fältström et al., 2023; Figueroa Poblete et al., 2025; Girdwood et al., 2024; King et al., 2021; Marigi et al., 2023; Marty-Diloy et al., 2025; Nyland et al., 2025; Simonsson et al., 2024; Zsidai et al., 2026) investigated the association between reinjury occurrence and 7 types of individual hop test performance, including side hop, 5-jump, single-leg drop jump, SLVJ, etc. (Table 2).

For the side hop, a meta-analysis of 3 studies (Fältström et al., 2023; Simonsson et al., 2024; Zsidai et al., 2026) (694 participants) found no significant association between achieving an LSI ≥ 90% and reinjury odds (OR = 1.00, 95% CI: 0.97 to 1.02, I^2 = 0%) (Figure 4), and the certainty of evidence was moderate. Limited-certainty evidence from one study (Fältström et al., 2023) reported significant differences in height-normalized hopping numbers between reinjury and non-reinjury groups.

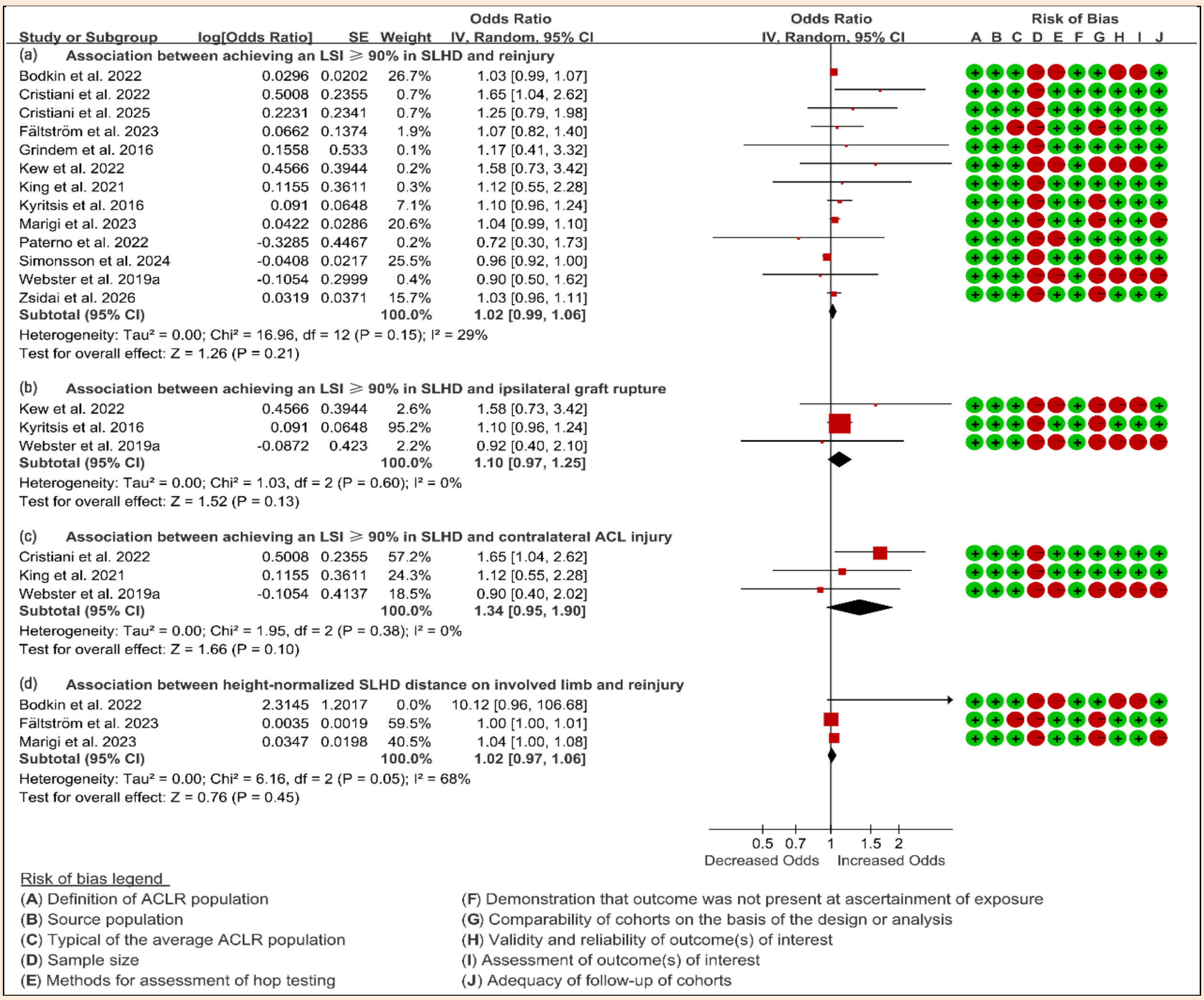

Figure 3. Forest plot of associations between measures of single-leg hop for distance (SLHD) and reinjury odds, and quality assessment of each study using modified Newcastle-Ottawa Scale: a) displays the associations between achieving LSI (limb symmetry index) ≥90% of SLHD and reinjury; b-c) display the subgroup analysis of ipsilateral graft rupture and contralateral ACL injury; d) displays the association between greater height-normalized distance of involved limb and reinjury.

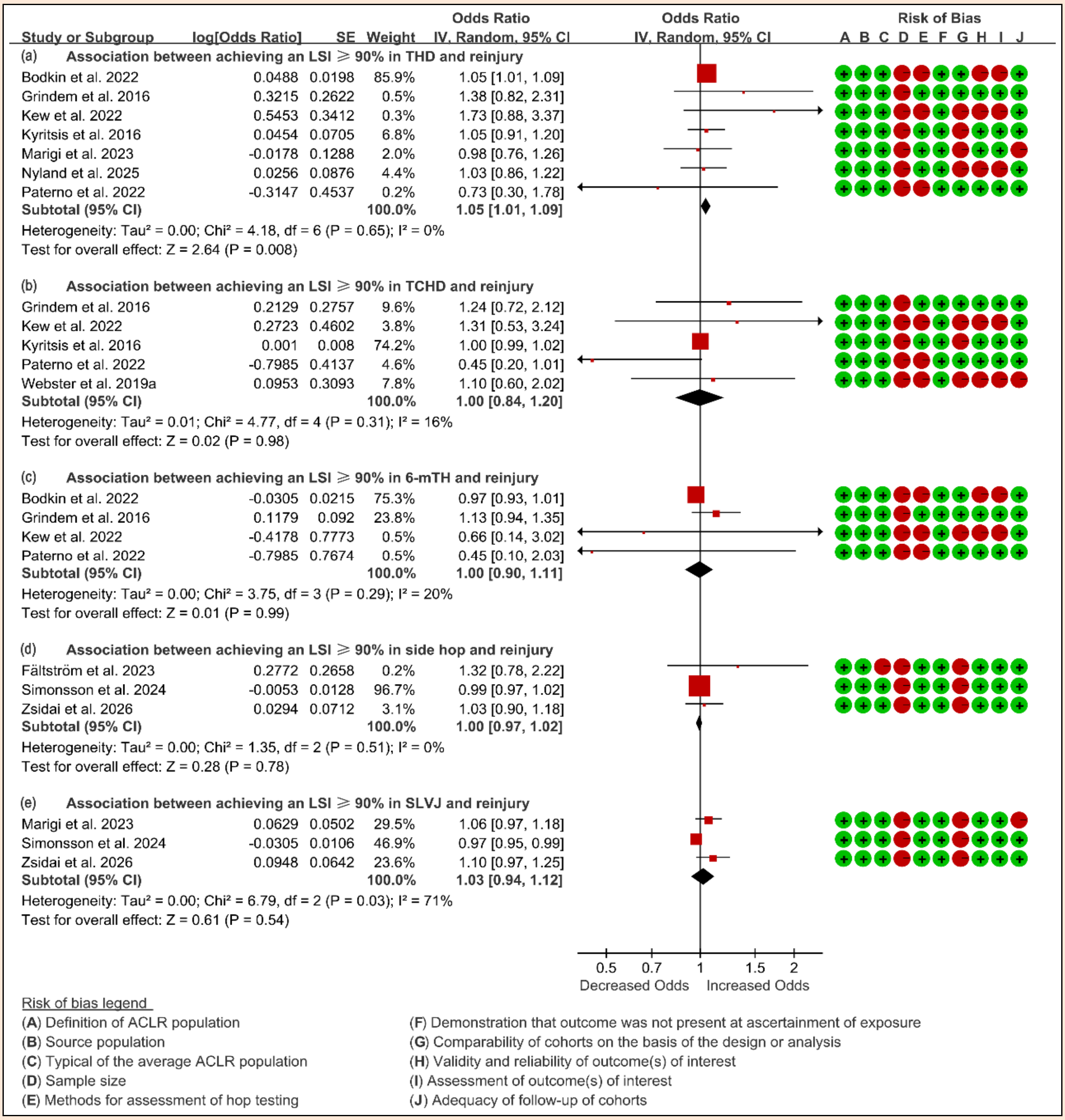

Figure 4. Forest plot displaying associations between achieving LSI (limb symmetry index) ≥ 90% in triple hop for distance (THD), triple crossover hop for distance (TCHD), 6-meter timed hop (6-mTH), side hop, single-leg vertical jump (SLVJ) and reinjury, and quality assessment of each study using modified Newcastle-Ottawa Scale.

For absolute hopping numbers on both involved and uninvolved limbs, findings were inconsistent: two studies (Girdwood et al., 2024; Marty-Diloy et al., 2025) found no significant differences, in contrast with one additional study (Fältström et al., 2023) (Table 4, Supplementary Table 5). Similarly, a meta-analysis of 3 studies (Marigi et al., 2023; Simonsson et al., 2024; Zsidai et al., 2026) involving 921 participants found no association between achieving an LSI ≥ 90% in SLVJ and reinjury odds (OR = 1.03, 95% CI: 0.94 to 1.12, I^2 = 71%) (Figure 4). The certainty of evidence was rated as low. In addition, a single study (Marigi et al., 2023) also reported no association between height-normalized jump length in SLVJ and reinjury (Table 4), providing limited certainty of evidence (Supplementary Table 5).

In addition, limited certainty of evidence from a single study (Fältström et al., 2023) suggested that both jump length and height-normalized length in the 5-jump test differed significantly between reinjury and non-reinjury groups (Table 4, Supplementary Table 5).

For hop test batteries, low certainty of evidence indicated no significant association with reinjury. Although one study (Van Melick et al., 2022) reported that achieving an LSI ≥ 90% in a hop battery was associated with decreased odds of reinjury, four additional studies (Figueroa Poblete et al., 2025; Paterno et al., 2022; Piussi et al., 2023;

Simonsson et al., 2024) reported no association despite using different combinations of hop tests. Similarly, no significant associations were found between the remaining hop test measures and reinjury risk, and the certainty of evidence ranged from limited to low (Table 4, Supplementary Table 5).

Table 4. Summary of findings from variables excluded from meta-analyses on associations between hop test measures and reinjury.

Study	Measure of hop test		
	LSI	Absolute value†	Height-normalized value†
Single-leg hop for distance			
Fältström et al., 2023	--	IL: 127 ± 23 vs. 120 ± 19; P = 0.102‡ UL: 128 ± 21 vs. 122 ± 18; P = 0.134‡	UL: 0.77 ± 0.13 vs. 0.73 ± 0.11; P = 0.093‡
Girdwood et al., 2024	☒	☒	IL: HR = 1.01 (0.99 - 1.02)§, ¶
Ithurburn et al., 2019	96.0 ± 7.0 vs. 94.1 ± 6.4; P > 0.05‡	☒	IL: P = 0.982†† UL: P = 0.133††
King et al., 2021	--	IL: 152.3 ± 27.0 vs. 154.9 ± 19.9; P = 0.562‡	☒
Marigi et al., 202	--	☒	☒
Marty-Diloy et al., 2025	☒	UL: 113.15 ± 63.2 vs. 121.2 ± 56.2; P = 0.483‡ IL: 108.2 ± 62.03 vs. 106.6 ± 54.8; P = 0.89‡	☒
Paterno et al., 2025	ipsilateral graft rupture: 98.9 ± 6.8; contralateral ACL injury: 95.9 ± 6.4; non-reinjury: 98.4 ± 4.9; P = 0.39‡	☒	☒
Triple hop for distance			
Bodkin et al., 2022	--	☒	IL: OR = 1.81 (0.81, 4.05)§; P = 0.150
Ithurburn et al., 2019	95.2 ± 6.4 vs. 95.4 ± 6.3; P > 0.05‡	☒	IL: P = 0.034†† UL: P = 0.027††
Marigi et al., 2023	--	☒	IL: 256 ± 63 vs. 254 ± 190; P = 0.19‡ UL: 93 ± 18 vs. 94 ± 67; P = 0.33‡
Marty-Diloy et al., 2025	☒	UL: 487.86 ± 111.32 vs. 434.81 ± 113.98; P = 0.19‡ IL: 469.94 ± 98.737 vs. 414.99 ± 114.09; P = 0.18‡	☒
Nyland et al., 2025	☒	UL: 324.7 ± 191.9 vs. 325.7 ± 166.1; P = 0.767‡ IL: 324.9 ± 191.3 vs. 317.8 ± 163.3; P = 0.832‡	☒
Paterno et al., 2025	ipsilateral graft rupture: 97.5 ± 8.0; contralateral ACL injury: 97.9 ± 5.4; non-reinjury: 99.0 ± 4.5; P = 0.73‡	☒	☒
Triple crossover hop for distance			
Ithurburn et al., 2019	95.5 ± 5.3 vs. 95.3 ± 7.6; P > 0.05‡	☒	IL: P = 0.569†† UL: P = 0.551††
Paterno et al., 2025	ipsilateral graft rupture: 96.4 ± 2.1; contralateral ACL injury: 98.7 ± 6.7; non-reinjury: 98.5 ± 5.0; P = 0.54‡	☒	☒
Webster et al., 2019a	ipsilateral graft rupture vs. non-reinjury: OR = 1.1 (.05 - 2.5) §; P > 0.05¶ contralateral ACL injury vs. non-reinjury: OR = 1.0 (0.4 - 2.5)§; P > 0.05¶	☒	☒
6-meter timed hop			
Bodkin et al., 2022	--	IL: OR = 0.65 (0.31, 1.36)§; P = 0.252	☒
Paterno et al., 2025	ipsilateral graft rupture: 101.0 ± 5.3; contralateral ACL injury: 100.3 ± 8.4; non-reinjury: 96.7 ± 7.1; P = 0.18‡	☒	☒

† hopping time for 6-meter timed hop, hopping numbers for side hop, hopping length for vertical jump, hopping distance for other hop tests; ‡ comparison between reinjury (the former) and non-reinjury (the latter) groups; § median (95% confidence interval); ¶ result was calculated based on achieving LSI ≥ 90% vs. <90%; †† data were presented as box plots; Abbreviations: --: data were included in meta-analysis; ☒: not reported; LSI: limb symmetry index; OR: odds ratio; HR: hazard ratio; IL: involved limb; UL: uninvolved limb.

Table 4. Continue…

Study	Measure of hop test: LSI	Absolute value†	Height-normalized value†
Side hop			
Fältström et al., 2023	--	IL: 41 ± 17 vs. 33 ± 13; P = 0.007‡ UL: 42 ± 15 vs. 36 ± 13; P = 0.049‡	IL: 0.25 ± 0.10 vs. 0.20 ± 0.08; P = 0.006‡ UL: 0.25 ± 0.09 vs. 0.21 ± 0.08; P = 0.042‡
Girdwood et al., 2024	☒	IL: HR = 1.00 (0.96 - 1.04) §, ¶ UL: HR = 1.02 (0.99 - 1.05)§, ¶	☒
Marty-Diloy et al., 2025	☒	UL: 50.04 ± 15.3 vs. 48.07 ± 13.8; P = 0.491‡ IL: 43.9 ± 16.9 vs. 41.2 ± 17.05; P = 0.44‡	☒
5-jump			
Fältström et al., 2023	--	IL: 922 ± 116 vs. 865 ± 88; P = 0.007‡	IL: 5.52 ± 0.67 vs. 5.15 ± 0.52; P = 0.003‡
Single-leg countermovement jump			
King et al., 2021	85.8 ± 13.2 vs. 84.4 ± 14.6; P = 0.627‡	IL: 12.1 ± 2.3 vs. 11.9 ± 2.4; P = 0.561‡	☒
Single-leg drop vertical jump			
King et al., 2021	78.1 ± 16.7 vs. 74.1 ± 14.8; P = 0.186‡	IL: 12.1 ± 3.2 vs. 12.4 ± 2.7; P = 0.564‡	☒
Marty-Diloy et al., 2025	☒	UL: 0.3 ± 0.5 vs. 0.25 ± 0.4; P = 0.559‡ IL: 0.4 ± 0.5 vs. 0.3 ± 0.5; P = 0.685‡	☒
Single-leg vertical jump			
Marigi et al., 2023	--	☒	IL: 17 ± 6 vs. 17 ± 12; P = 0.17‡ UL: 19 ± 6 vs. 20 ± 13; P = 0.62‡
20-meter timed hop			
Nyland et al., 2025	99.282 ± 3.9787 vs. 97.556 ± 6.1697; P = 0.42‡	IL: 4.8412 ± 0.8934 vs. 5.3701 ± 1.3347; P = 0.21‡ UL: 4.7765 ± 0.7571 vs. 5.2257 ± 1.1548; P = 0.27‡	☒
20-meter timed crossover hop			
Nyland et al., 2025	100.36 ± 5.1664 vs. 99.081 ± 6.124; P = 0.45‡	IL: 5.5824 ± 1.1064 vs. 6.3701 ± 1.7427; P = 0.19‡ UL: 5.6529 ± 1.262 vs. 6.3701 ± 1.7851; P = 0.28‡	☒
Hop test battery			
Figueroa et al., 2025	OR = 2.2 (0.6 - 5.11)§	☒	☒
Paterno et al., 2022	OR = 0.61 (0.3 - 1.4)§; P = 0.24d	☒	☒
Piussi et al., 2023	HR = 0.82 (0.47 - 1.44)§, P = 0.50d	☒	☒
Simonsson et al., 2024	OR = 0.65 (0.31, 1.33)§, P = 0.24d	☒	☒
van Melick et al., 2022	ARR (absolute risk reduction) = 11%, P = 0.047d	☒	☒

† hopping time for 6-meter timed hop, hopping numbers for side hop, hopping length for vertical jump, hopping distance for other hop tests; ‡ comparison between reinjury (the former) and non-reinjury (the latter) groups; § median (95% confidence interval); ¶ result was calculated based on achieving LSI ≥ 90% vs. <90%; †† data were presented as box plots. Abbreviations: --: data were included in meta-analysis; ☒: not reported; LSI: limb symmetry index; OR: odds ratio; HR: hazard ratio; IL: involved limb; UL: uninvolved limb.

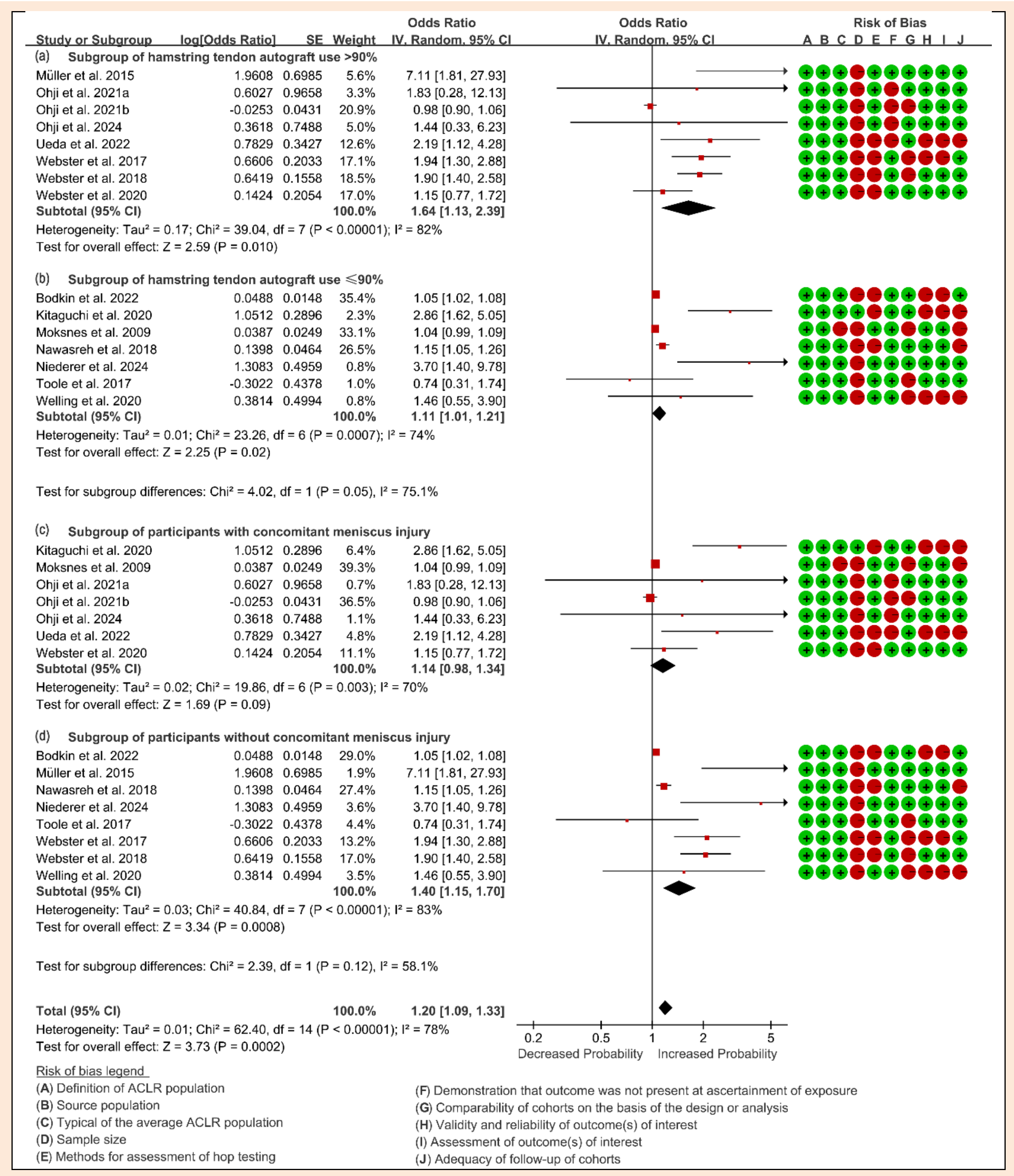

Figure 5. Forest plot displaying subgroup analyses of hamstring tendon autograft use and concomitant meniscus injury in association between achieving LSI (limb symmetry index) ≥ 90% in single-leg hop for distance (SLHD) and RTS (return to sports), and quality assessment of each study using modified Newcastle-Ottawa Scale.

Subgroup and sensitivity analyses

Subgroup analyses regarding graft type, concomitant meniscal injury, timing of hop test, measures of RTS and follow-up duration for the association between LSI performance of SLHD and RTS were conducted to address significant heterogeneity, which was not feasible for other hop tests due to inadequate data for stratification. A significant subgroup difference was observed according to the proportion of participants receiving HT autografts (I^2 = 75.1%, p = 0.05), with stronger association found in studies with > 90% HT autograft use (OR = 1.64, 95% CI: 1.13 to 2.39, I^2 = 82%) compared with those with ≤ 90% (OR = 1.11, 95% CI: 1.01 to 1.21, I^2 = 74%) (Figure 5). In addition, subgroup analysis found achieving an LSI ≥ 90% in SLHD was associated with increased likelihood of RTS in participants without meniscal injury (4412 participants; OR = 1.40, 95% CI: 1.15 to 1.70, I^2 = 83%), but not in those with meniscus injury (903 participants; OR = 1.14, 95% CI: 0.98 to 1.34, I^2 = 70%) (Figure 5). Additional subgroup analyses confirmed consistent significant associations between achieving an LSI ≥ 90% in SLHD and RTS probability across all other subgroups, regardless of timing of hop testing (≥ 1 year postoperatively vs. < 1 year postoperatively), measures of RTS (quantitative scores vs. patient-reported dichotomous outcomes) and follow-up duration (> 2 years vs. ≤ 2 years) (Figure 6, Supplementary Figure 2).

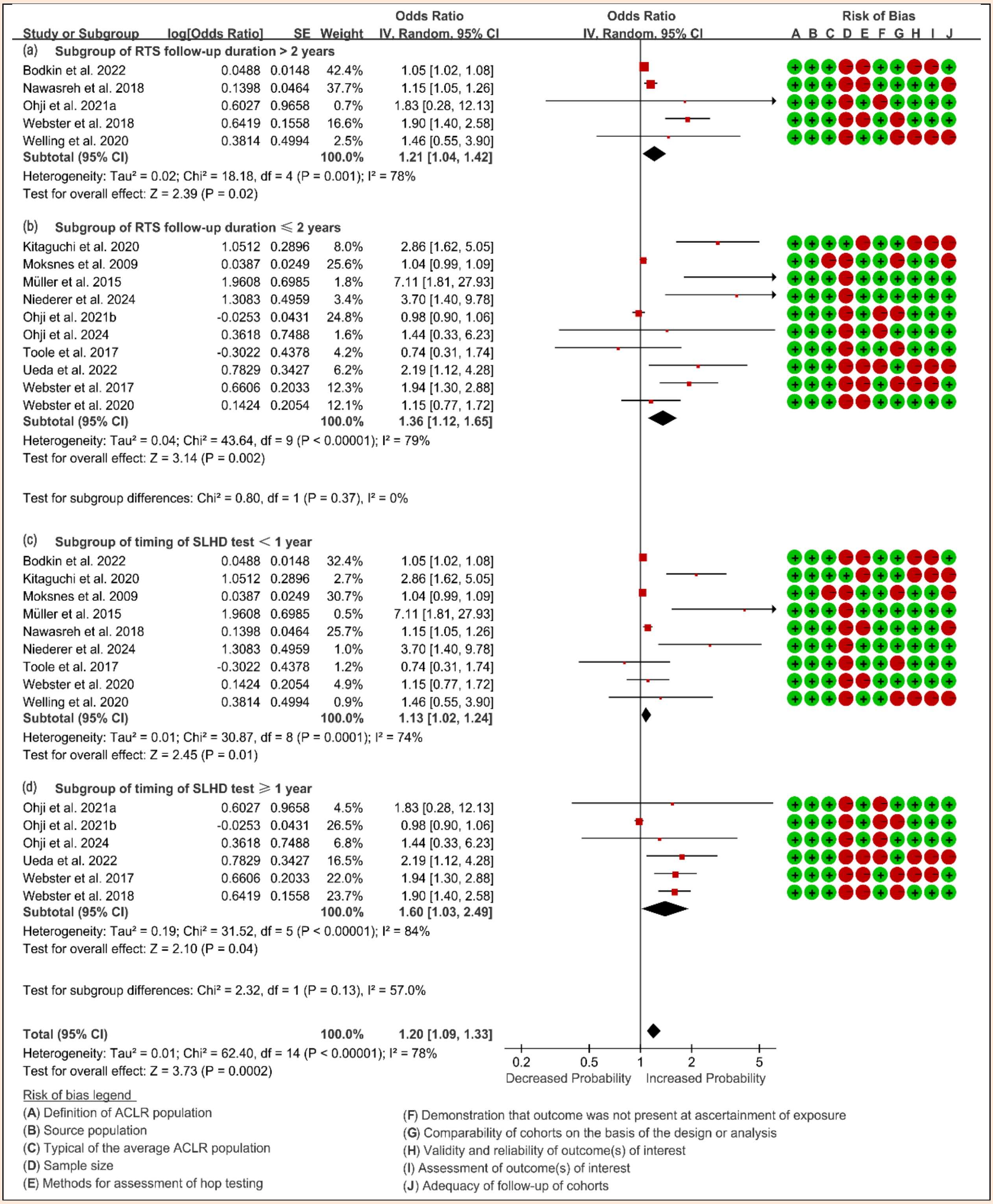

Figure 6. Forest plot displaying subgroup analyses of follow-up duration and testing timing in association between achieving LSI (limb symmetry index) ≥ 90% in single-leg hop for distance (SLHD) and RTS (return to sports), and quality assessment of each study using modified Newcastle-Ottawa Scale.

Furthermore, random-effects meta-regressions were performed to investigate the potential influence of study-level variables on the association between the LSI in SLHD and RTS. In univariable analyses, no study-level variables were significantly associated with effect size. In multivariable meta-regression, the model including meniscus status and follow-up duration was statistically significant ($p = 0.006$). Both meniscus status ($\beta = -0.520$, $p = 0.003$) and follow-up duration ($\beta = -0.047$, $p = 0.002$) were independently associated with effect size. However, across all models, the proportion of between-study variance explained by the moderators was negligible ($R^2 = 0.00\%$), and considerable residual heterogeneity remained (residual I^2 range: 65.83% to 80.77%) (Supplementary Table 6).

Additionally, to determine whether meeting an LSI ≥ 90% of SLHD had different effects on the prediction of ipsilateral graft rupture and contralateral ACL injury, additional meta-analyses were conducted. Neither outcome showed a significant association. Specifically, for ipsilateral graft rupture, three studies (Cristiani et al., 2022; King et al., 2021; Webster and Feller, 2019) (n = 526) reported a pooled OR of 1.10 (95% CI: 0.97 to 1.25, $I^2 = 0\%$); for contralateral ACL injury, three studies (Kew et al., 2022; Kyritsis et al., 2016; Webster and Feller, 2019) (n = 5787) reported a pooled OR of 1.34 (95% CI: 0.95 to 1.90, $I^2 = 0\%$) (Figure 3).

Sensitivity analysis using the leave-one-out method revealed that the pooled effect estimates remained significantly associated between SLHD LSI and RTS (Supplementary Table 7). Although all I^2 values exceeded 70%, the findings indicate that the overall heterogeneity was not driven by any single study, thereby supporting the robustness of this association. A significant association was also found (9 studies, OR = 1.30, 95% CI: 1.05 to 1.62, $I^2 = 77\%$) when dropping studies with a high risk of bias, strengthening this robustness (Supplementary Figure 1). However, the funnel plot with trim-and-fill imputation (Duval and Tweedie, 2000) suggested potential publication bias (imputed 6 studies; OR = 1.06, 95% CI: 0.95 to 1.18) (Supplementary Figure 4), which may have influenced the observed association between LSI of SLHD and RTS. This analysis was not performed for other outcomes because of insufficient data.

Discussion

This review found that achieving an LSI ≥ 90% in SLHD and TCHD was significantly associated with a higher likelihood of return to preinjury level of sports; achieving an LSI ≥ 90% in THD was significantly associated with an increased risk of reinjury following ACLR. Associations between other hop test measures and RTS, as well as reinjury risk, remained nonsignificant, inconsistent or limited. Given the small effect size, the association between the LSI in THD and reinjury should be interpreted with appropriate caution.

Associations between hop test performance and RTS

This review found increased probability of RTS among individuals who achieved an LSI ≥ 90% in SLHD and TCHD (Figure 2), which aligns with previous reviews (Ardern et al., 2014; Gill et al., 2024b; Losciale et al., 2020; West et al., 2023). Although the effect sizes were modest, subgroup and sensitivity analyses demonstrated the robustness of the findings. However, these results should be interpreted cautiously due to the identified between-study heterogeneity and potential publication bias. Therefore, while SLHD and TCHD may provide clinically relevant information regarding RTS, they should be considered as components of a comprehensive, multidimensional RTS assessment rather than standalone criteria.

In contrast, achieving LSI ≥ 90% in THD was not significantly associated with RTS or 6-mTH (Figure 2), which differed from previous evidence (West et al., 2023). The discrepancy may be attributed to differences in study populations. West et al. (2023) recruited individuals with ACL injuries treated either operatively or non-operatively, whereas the present review focused exclusively on those treated operatively. Differences in recovery trajectories and rehabilitation strategies among these two populations (Grindem et al., 2014) may influence muscular endurance and fatigue resistance, thereby affecting performance on longer-duration hop tests (Komi, 2000; Kotsifaki et al., 2022a).

The association between SLHD symmetry and RTS appeared to be influenced by several clinical factors. Our subgroup analyses identified graft type as a potential effect modifier. Specifically, the association between SLHD LSI ≥ 90% and RTS was stronger in the subgroup with the use of HT autografts > 90% (OR = 1.64) compared with the ≤ 90% subgroup (OR = 1.11), with high between-subgroup heterogeneity ($I^2 = 75.1\%$) (Figure 5). This finding may partly reflect differences in functional recovery after different graft choices, as patients receiving BPTB autografts have been reported to experience a higher risk of anterior knee pain and impaired quadriceps neuromuscular function, which may negatively influence psychological confidence and sports participation (Hui et al., 2011; Spindler et al., 2004). However, this finding should be interpreted as an effect of populations predominantly receiving different graft types rather than a direct effect of graft choice itself.

In addition, the subgroup analyses found that achieving an SLHD LSI ≥ 90% was significantly associated with RTS in individuals without meniscal injury, but not in those with meniscal injury (Figure 5). The meta-regression further supported this finding, showing a significant negative association between meniscal injury and RTS effect estimates (Supplementary Table 6). Given the role of the meniscus in load distribution, knee stability, and proprioception (Flandry and Hommel, 2011; Fox et al., 2012), concomitant meniscal injuries may impair neuromuscular control and functional recovery, reducing the ability of hop symmetry to discriminate RTS outcomes. Therefore, patients with combined ACLR and meniscal injury may require additional assessments beyond hop test performance, such as lower-limb muscle strength, movement quality, psychological readiness, and other established RTS criteria. Further investigation should provide more detailed reporting of meniscal treatment status to better evaluate its potential influence on hop performance and RTS outcome.

Furthermore, our meta-regression analysis also identified follow-up duration as a significant moderator

(Supplementary Table 6), suggesting that the association between SLHD symmetry and RTS may diminish over time. This finding appeared to be strengthened by subgroup analyses, as the strength of the association was weaker in studies with longer follow-up duration (Figure 6). As neuromuscular control, muscle strength, and functional performance are largely restored within the first 2 years following ACLR (Buckthorpe et al., 2024), factors influencing long-term RTS decisions become more multifaceted and complex, such as fear of reinjury, restoration of sport-specific skills, and return to high-level competition (Nagelli and Hewett, 2017). However, these results should be interpreted cautiously due to the limited number of studies (5 studies), high dropout rate (20.02%) during follow-up, and the between-study heterogeneity that the identified moderators did not explain (R^2 = 0%).

Our subgroup analyses and meta-regression did not identify potential covariates that explained the substantial between-study heterogeneity, with R^2 of 0% across all models and persistently high residual I^2 values (Supplementary Table 6). This suggests that additional unmeasured factors, such as patient characteristics (e.g., sports type and activity level), surgical factors (e.g., reconstruction technique and meniscal treatment), and rehabilitation adherence, may further contribute to the observed variability. Future high-quality studies should therefore incorporate objective RTS measures, adequately control for relevant covariates and confounders, and report absolute risk estimates alongside relative measures to better establish the clinical utility of hop testing.

Consequently, these findings support the inclusion of SLHD or TCHD tests as essential components of a multifaceted RTS assessment criterion, particularly for patients undergoing HT autograft reconstruction, without concomitant meniscal injuries during the first 2 years after ACLR. Due to substantial heterogeneity, potential publication bias and limited certainty of evidence, future longitudinal studies are needed to better clarify their roles in making RTS decisions.

Associations between hop test performance and reinjury

In contrast to previous systematic reviews (Cronström et al., 2023; Losciale et al., 2020), our review identified a statistically significant association between achieving an LSI ≥ 90% in THD and an increased risk of reinjury (Figure 3). However, this finding should be interpreted cautiously, given the small effect size, limited number of studies, and inconsistency with previous evidence. The RTS criteria used in the included studies were generally homogeneous beyond hop testing (Supplementary Table 3), suggesting that differences in non-hop-test evaluations were unlikely to explain the observed association. Additionally, the homogeneity (I^2 = 0%, Cochran's Q = 4.18, p = 0.65) should be interpreted cautiously, as it may be limited in statistical power, given the limited number of studies. Furthermore, very-low to moderate certainty and lack of significant associations between other hop test outcomes and reinjury indicate that hop test alone provides limited value for identifying reinjury risk after ACLR.

The limited association between hop tests and reinjury risk may be explained by the inability of traditional hop test metrics, such as LSI and distance, to capture underlying deficits in movement quality that are more related to ACL loading (Kotsifaki et al., 2020; Xergia et al., 2015). Non-contact ACL injury, accounting for the majority of ACL injuries (Della Villa et al., 2021; Lucarno et al., 2021), occurs as rapidly as 17 to 50 milliseconds after initial ground contact (Koga et al., 2010; Krosshaug et al., 2007) and aberrant biomechanical patterns, such as excessive knee valgus, greater asymmetry in knee extensor moments, and decreased knee flexion angles, may contribute to elevated ACL loading (Gill et al., 2024a; Peebles et al., 2022). However, traditional hop test outcomes, such as LSI or hopping distance, primarily quantify overall performance rather than movement quality during the landing phase (Kotsifaki et al., 2020). Moreover, LSI in hop tests may overestimate functional recovery because the contralateral limb also exhibited persistent neuromuscular deficits (Girdwood et al., 2024) and movement quality abnormalities may remain despite meeting symmetry thresholds (Kotsifaki et al., 2022a; Kotsifaki et al., 2022b). Therefore, hop-test symmetry may not provide sufficient sensitivity to identify biomechanical deficiencies relevant to reinjury prevention.

Another potential explanation for the limited association is that laboratory-based hop tests may not adequately represent the complexity of competitive sports. Laboratory- or clinical-based hop tests are typically performed in predictable, single-plane conditions and do not incorporate sport-specific challenges, such as opponent interaction (McLean et al., 2004), unplanned movement (King et al., 2018) and divided attention (Almonroeder et al., 2019). Moreover, psychological factors, including fear of reinjury and low self-efficacy, may influence movement quality (Zhou et al., 2023), readiness for RTS (Niederer et al., 2025; Paterno et al., 2025) and functional performance (Beischer et al., 2019), which may further be associated with reinjury occurrence.

In addition, the best passing cutoff values for hop tests remain uncertain. Although an LSI threshold of 90% is widely used (Barber-Westin and Noyes, 2011; Thomeé et al., 2011), persistent functional and biomechanical deficits have been observed in individuals who meet this criterion (Gill et al., 2024a; Kotsifaki et al., 2022a; Kotsifaki et al., 2022b). Further research using longitudinal designs and appropriate predictive modelling is needed to establish clinically meaningful thresholds. Furthermore, future studies should analyze ipsilateral graft rupture and contralateral ACL injury separately rather than treating them as a single reinjury outcome, as these outcomes may involve different mechanisms and not be equally predicted by hop-test performance (Cronström et al., 2023; Cronström et al., 2021).

Consequently, LSI or distance-related measures on hop tests may be unable to predict reinjury risk after ACLR. Future research may move beyond isolated hop performance and develop multidimensional risk assessment models incorporating environmental adaptability and movement quality to improve reinjury risk stratification and promote safer RTS decisions.

Limitations

This review has several limitations. Firstly, the certainty of evidence, particularly for RTS outcomes, was rated low or very low under the GRADE framework, primarily due to the significant heterogeneity and potential reporting bias. High heterogeneity may be partly explained by graft type, but likely stems from unmeasured clinical or methodological factors. Reporting bias is largely based on the inadequately repeated investigation. Additionally, participant attrition during follow-up may have introduced potential attrition bias. Therefore, high-quality, large-scale prospective cohort studies are warranted to strengthen the evidence. In addition, our search strategy prioritized studies reporting RTS as a primary outcome. This focus may have excluded some reinjury-focused cohort studies not emphasizing RTS in titles or abstracts. However, comparison with prior systematic reviews showed our study selection was comparable in scope, indicating that the findings were not materially influenced by the search strategy. Finally, we were unable to determine whether surgical factors, such as graft type and concomitant meniscal procedures, modified the associations between hop test performance and RTS or reinjury because these variables were inconsistently reported and data were limited.

Conclusion

Low certainty of evidence suggests that achieving an LSI ≥ 90% in single-leg hop for distance and triple crossover hop for distance is associated with a higher likelihood of RTS following ACLR, particularly within the first two years following ACLR and among individuals reconstructed with hamstring autografts and without concomitant meniscal injuries. Moderate certainty of evidence suggests a modest association between achieving an LSI ≥ 90% in triple hop for distance and a higher likelihood of ACL reinjury. Although these associations were small in magnitude, the findings suggest that functional performance assessed by hop tests may reflect readiness for RTS but does not necessarily correspond to a lower risk of reinjury, highlighting the limitations of relying solely on hop performance when making RTS decisions. Therefore, clinicians may consider incorporating SLHD/TCHD LSI values as part of a broader, multifactorial RTS assessment framework. Incorporating movement quality, neuromuscular control, and contextual factors may improve reinjury risk stratification and enhance safer RTS decision-making.

Acknowledgements

This study was sponsored by the National Natural Science Foundation of China (Grant No. 82402985) and Shanghai Pujiang Program (Grant No. 24PJC069). The authors have declared that there are no conflicts of interest in the authorship and publication of this contribution. The datasets generated and analyzed in this study are not publicly available, but are available from the corresponding author who organized the study upon reasonable request. All experimental procedures were conducted in compliance with the relevant legal and ethical standards of the country where the study was performed. The authors declare that no Generative AI or AI-assisted technologies were used in the writing of this manuscript.

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Key points

- A limb symmetry index (LSI) ≥ 90% in the single-leg hop for distance and triple crossover hop for distance was associated with a higher likelihood of successful return to sports following ACLR.
- An LSI ≥ 90% in the trip hop for distance was associated with a modestly higher risk of ACL reinjury following ACLR.
- An LSI threshold of ≥ 90% was the most frequently adopted criterion for hop test assessment after ACLR.
- Current evidence suggests that hop tests are more useful for assessing RTS readiness than reinjury risk, supporting the development of more comprehensive RTS assessment criteria.

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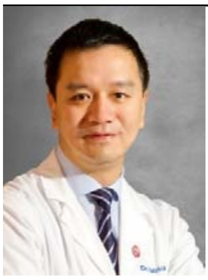

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Supplementary Materials

Supplementary Table 1. Systematic search strategy.

PubMed	(("anterior cruciate ligament" OR ACL OR (acl injuries[MeSH Terms]) OR (acl tears[MeSH Terms])) AND (reconstruction OR surgery OR operation)) AND ("return to play" OR "return to sport*" OR "return to activit*" OR "return to performance" OR RTS OR RTP) AND (hop OR hops OR hopping OR jump* OR land*)
Web of Science	((TS = ("anterior cruciate ligament" OR ACL)) AND TS = (reconstruction OR surgery OR operation)) AND TS = ("return to play" OR "return to sport*" OR "return to activit*" OR "return to performance" OR RTS OR RTP) AND TS = (hop* OR jump* OR land*)
SPORTDiscus with Full Text	TX ("anterior cruciate ligament" OR ACL) AND TX (reconstruction or surgery or operation) AND TX ("return to play" OR "return to sport*" OR "return to activit*" OR "return to performance" OR RTS OR RTP) AND TX (hop* OR jump* OR land*)
Medline	TX ("anterior cruciate ligament" OR ACL) AND TX (reconstruction or surgery or operation) AND TX ("return to play" OR "return to sport*" OR "return to activit*" OR "return to performance" OR RTS OR RTP) AND TX (hop* OR jump* OR land*)

Supplementary Table 2. The explanation for the factors given for the modified GRADE (Grading of Recommendations Assessment, Development and Evaluation) assessment

	Downgrade factor					Upgrading factor	
	Study limitation	**Inconsistency**	**Imprecision**	**Indirectness**	**Reporting bias**	**Effect size**	**Dose-response**
Description	Evidence base contains < 30% of all participants from studies rated overall low risk of bias (low quality in seven or more of the ten domains).	Pooled estimate has substantial or considerable heterogeneity (I^2 > 50%), OR there is large variability in point estimates across studies, with estimates varying in direction and little or no overlap of confidence intervals.	95%CI are excessively wide about the pooled effect estimate, OR evidence base contains few studies with small populations and most provide imprecise estimates.	Differences in population, exposure, or outcome thought to substantially alter pooled estimate, limiting applicability and generalizability.	Evidence of reporting deficiencies and publication bias from funnel plot and Egger's test if ≥ 10 studies, OR the relationship has not been repeatedly investigated (< 10 studies).	Moderate to large pooled effect estimate (OR > 2.5).	Evidence of a well-defined pattern (linear or otherwise) suggesting an exposure response gradient is present.
Exception	Unless sensitivity analysis restricted to studies rated overall low risk of bias explains methodological heterogeneity. Then, report pooled estimate from overall low risk of bias studies.	Unless subgroup analyses explain clinical heterogeneity in pooled estimate. Then, report estimates from each subgroup.					
Levels of confidence in the certainty of evidence							
High	We have high confidence in the estimate: the true measure of association likely lies close to that of the estimate.						
Moderate	We have moderate confidence in the estimate: the true measure of association is likely close to the estimate, but possibly substantially different.						
Low	We have low confidence in the estimate: the true measure of association may differ substantially from the estimate.						
Very low	We have very low confidence in the estimate: the true measure of association will likely differ substantially from the estimate.						
Inconsistent	We could not conclude a consistent result based on all the investigations.						
Limited	Only one study was included in the outcome.						

Supplementary Table 3. Evaluation items except hop testing and measurements of outcome for each study

Study	RTS/ reinjury: n (%)	Evaluation item(s) except hop testing	Measurement of RTS/ reinjury
Return to sports			
Bodkin et al., 2022	155 (80.73%)	subjective function (KOOS, IKDC); isokinetic strength (knee-extensor and -flexor)	self-reported
Faleide et al., 2021	43 (41.75%)	subjective function (IKDC, ACL-RSI); isokinetic strength (knee-extensor)	self-reported
Ithurburn et al., 2019	70 (71.43%)	subjective function (KOOS); isokinetic strength (knee-extensor and -flexor)	Tegner activity score
Jang et al., 2014	51 (76.12%)	subjective function (IKDC, Lysholm score); isokinetic strength (knee-extensor and -flexor); co-contraction test; carioca test; shuttle run test; knee laxity measurement	self-reported
Kim et al., 2022	67 (78.82%)	subjective function (ACL-RSI, Cincinnati knee rating system, KOOS, Lysholm score, VAS); isokinetic strength (knee-extensor and -flexor); knee laxity measurement	Tegner activity score
Kitaguchi et al., 2020	101 (81.45%)	subjective function (IKDC, ACL-RSI, NRS); isokinetic strength (knee-extensor and -flexor); knee laxity measurement	self-reported
Legnani et al., 2024	18 (54.55%)	subjective function (IKDC, ACL-RSI)	Tegner activity score
Moksnes et al., 2009	35 (70.00%)	subjective function (KOS-ADLS, IKDC, VAS); knee laxity measurement	criteria described by Hefti et al.,(1993)
Müller et al., 2015	31 (79.49%)	subjective function (IKDC, TSK, ACL-RSI); isometric strength (knee-extensor and -flexor)	criteria described by Hefti et al.,(1993)
Nawasreh et al., 2018	49 (61.25%)	subjective function (KOS-ADLS, GRS); isometric strength (knee-extensor)	self-reported
Niederer et al., 2024	40 (45.45%)	subjective function (ACL-RSI, KOOS, TSK)	self-reported + Tegner activity score
Niederer et al., 2025	104 (75.36%)	subjective function (ACL-RSI, KOOS, TSK)	self-reported + Tegner activity score
Novaretti et al., 2018	33 (56.90%)	subjective function (IKDC, Lysholm score); isokinetic strength; postural stability analysis	Tegner activity score
Ohji et al., 2024	39 (60.00%)	subjective function (NRS); isokinetic strength (knee-extensor and -flexor); knee laxity measurement; ROM deficit (knee flexion and extension)	sefl-reported + PoSAP
Ohji et al., 2021a	28 (63.64%)	isokinetic strength (knee-extensor and -flexor); knee laxity measurement; knee joint effusion (stroke test); ROM deficit (knee flexion and extension)	sefl-reported + PoSAP
Ohji et al., 2021b	43 (58.90%)	subjective function (TSK); isokinetic strength (knee-extensor and -flexor)	sefl-reported + PoSAP
Senorski et al., 2017	52 (33.12%)	subjective function (KOOS, K-SES, PAS); isotonic strength (knee-extensor and -flexor)	Tegner activity score
Toole et al., 2017	76 (66.09%)	subjective function (IKDC); isokinetic strength (knee-extensor and -flexor)	Tegner activity score
Ueda et al., 2022	95 (65.97%)	subjective function (IKDC); isokinetic strength (knee-extensor and -flexor); knee laxity measurement	self-reported
Webster et al., 2017	609 (25.23%)	subjective function (IKDC, SANE); ROM deficit (knee flexion); knee laxity measurement	self-reported
Webster et al., 2018	569 (39.51%)	subjective function (IKDC); knee laxity measurement	Cincinnati Sports Activity Scale
Webster et al., 2019b	135 (60.81%)	subjective function (IKDC, ACL-RSI); ROM deficit (knee flexion and extension); knee laxity measurement	self-reported
Webster et al., 2020	163 (40.45%)	subjective function (IKDC, ACL-RSI); isokinetic strength (knee-extensor)	Marx Activity Rating Scale
Welling et al., 2020	46 (71.88%)	subjective function (IKDC, ACL-RSI); isokinetic strength (knee-extensor); Landing Error Scoring System	self-reported
Reinjury			
Bodkin et al., 2022	44 (28.39%)	subjective function (KOOS, IKDC); isokinetic strength (knee-extensor and -flexor)	self-reported
Cristiani et al., 2022	252 (4.67%)	isokinetic strength (knee-extensor and -flexor)	medical records
Cristiani et al., 2025	170 (9.01%)	isokinetic strength (knee-extensor and -flexor); ROM deficit (knee extension); knee laxity measurement	medical records

KOOS: Knee Osteoarthritis Outcome Score; IKDC: International Knee Documentation Committee; ACL-RSI: Anterior Cruciate Ligament–Return to Sport after Injury questionnaire; VAS: Visual analog scale; NRS: Numerical rating scale; KOS-ADLS: Knee Outcome Survey Activities of Daily Living Scale; TSK: Tampa Scale for Kinesiophobia; GRS: Global Rating Score; K-SES: knee self-efficacy scale; PAS: physical activity scale; SANE: Single Assessment Numeric Evaluation; ROM: range of motion; PoSAP: Postoperative Subjective Athletic Perfor-mance; NR: not reported; MRI: magnetic resonance imaging.

Supplementary Table 3. Continue…

Study	RTS/ reinjury: n (%)	Evaluation item(s) except hop testing	Measurement of RTS/ reinjury
		Reinjury	
Fältström et al., 2023	28 (23.93%)	star excursion balance test	medical records
Figueroa et al., 2025	13 (13.68%)	repeat sprint ability; proagility test; functional movement screen	MRI
Girdwood et al., 2024	33 (28.21%)	subjective function (KOOS)	self-reported
Grindem et al., 2016	24 (24.00%)	subjective function (KOOS, GRS); isokinetic strength (knee-extensor)	medical records
Ithurburn et al., 2019	26 (27.08%)	subjective function (KOOS); isokinetic strength (knee-extensor and -flexor)	NR
Kew et al., 2022	28 (28.00%)	subjective function (KOOS, IKDC, TSK); isokinetic strength (knee-extensor and -flexor)	self-reported
King et al., 2021	55 (47.83%)	subjective function (IKDC, ACL-RSI); isokinetic strength (knee-extensor and -flexor)	MRI
Kyritsis et al., 2016	26 (16.46%)	isokinetic strength (knee-extensor and -flexor); running t test	medical records
Marigi et al., 2023	59 (17.15%)	isokinetic strength (knee-extensor and -flexor)	medical records
Marty-Diloy et al., 2025	27 (9.44%)	subjective function (IKDC, ACL-RSI); isokinetic strength (knee-extensor and -flexor)	self-reported
Nyland et al., 2025	17 (8.33%)	subjective function (KOOS, GRS); knee laxity measurement	NR
Paterno et al., 2022	35 (22.01%)	subjective function (IKDC); isometric strength (knee-extensor)	MRI
Paterno et al., 2025	20 (39.22%)	subjective function (IKDC, KOOS); isokinetic strength (knee-extensor and -flexor)	MRI
Piussi et al., 2023	51 (12.17%)	subjective function (ACL-RSI, KOOS); isokinetic strength (knee-extensor and -flexor)	NR
Simonsson et al., 2024	196 (84, 12%)	isotonic strength (knee-extensor and -flexor)	self-reported
van Melick et al., 2022	7 (7.22%)	subjective function (KOOS, K-SES); isokinetic strength (knee-extensor and -flexor, hip-abductor); Landing Error Scoring System	self-reported
Webster et al., 2019a	95 (28.88%)	subjective function (IKDC); ROM deficit (knee flexion and extension); knee laxity measurement	self-reported
Zsidai et al., 2026	40 (11.63%)	subjective function (KOOS, ACL-RSI, K-SES); isokinetic strength (knee-extensor and -flexor)	medical records

KOOS: Knee Osteoarthritis Outcome Score; IKDC: International Knee Documentation Committee; ACL-RSI: Anterior Cruciate Ligament–Return to Sport after Injury questionnaire; VAS: Visual analog scale; NRS: Numerical rating scale; KOS-ADLS: Knee Outcome Survey Activities of Daily Living Scale; TSK: Tampa Scale for Kinesiophobia; GRS: Global Rating Score; K-SES: knee self-efficacy scale; PAS: physical activity scale; SANE: Single Assessment Numeric Evaluation; ROM: range of motion; PoSAP: Postoperative Subjective Athletic Perfor-mance; NR: not reported; MRI: magnetic resonance imaging.

Supplementary Table 4. **Quality assessment of each study using Modified Newcastle Ottawa Scale.**

Study	Selection Bias				Exposure Bias		Comparability Bias	Outcome Bias		
	Definition of population	Source population	Typical of average population	Sample size	How performance using hop test(s) was decided	Demonstrates outcome was not present at time of hop testing	Comparability of cohort on the bias of the design or analysis	Validity and reliability of outcomes	Assessment of outcome(s) of interest	Adequacy of follow up
Bodkin et al., 2022	Low	Low	Low	High	High	Low	Low	High	High	Low
Cristiani et al., 2022	Low	Low	Low	High	Low	Low	Low	Low	Low	Low
Cristiani et al., 2025	Low	Low	Low	High	Low	Low	Low	Low	Low	Low
Faleide et al., 2021	Low	Low	Low	High	Low	Low	Low	High	High	High
Figueroa et al., 2025	Low	Low	Low	Low	High	Low	High	Low	Low	Low
Fältström et al., 2023	Low	Low	High	High	Low	Low	High	Low	Low	Low
Girdwood et al., 2024	Low	Low	Low	High	Low	Low	Low	High	High	High
Grindem et al., 2016	Low	Low	Low	High	Low	Low	Low	Low	Low	Low
Ithurburn et al., 2019	Low	Low	Low	High	Low	Low	High	Low	Low	High
Jang et al., 2014	Low	Low	High	High	High	Low	High	High	High	High
Kew et al., 2022	Low	Low	Low	High	High	Low	High	High	High	Low
Kim et al., 2022	Low	Low	Low	High	High	Low	High	Low	Low	Low
King et al., 2021	Low	Low	Low	High	Low	Low	Low	Low	Low	Low
Kitaguchi et al., 2020	Low	Low	Low	Low	High	Low	Low	High	High	High
Kyritsis et al., 2016	Low	Low	Low	High	Low	Low	High	Low	Low	Low
Legnani et al., 2024	Low	Low	Low	Low	Low	Low	High	Low	Low	Low
Marigi et al., 2023	Low	Low	Low	High	Low	Low	High	Low	Low	High
Marty-Diloy et al., 2025	Low	Low	Low	High	Low	Low	High	High	High	Low
Moksnes et al., 2009	Low	Low	High	High	Low	Low	High	Low	Low	High
Müller et al., 2015	Low	Low	Low	High	Low	Low	Low	Low	Low	Low
Nawasreh et al., 2018	Low	Low	Low	High	High	Low	Low	Low	Low	High
Niederer et al., 2024	Low	Low	Low	High	Low	Low	Low	Low	Low	Low
Niederer et al., 2025	Low	Low	Low	High	High	Low	High	Low	Low	Low
Novaretti et al., 2018	Low	Low	Low	Low	High	Low	Low	Low	Low	High
Nyland et al., 2025	Low	Low	Low	High	Low	Low	High	High	High	Low
Ohji et al., 2024	Low	Low	Low	High	Low	High	Low	Low	Low	Low
Ohji et al., 2021a	Low	Low	Low	High	Low	High	Low	Low	Low	Low
Ohji et al., 2021b	Low	Low	Low	High	Low	High	High	Low	Low	Low
Paterno et al., 2022	Low	Low	Low	High	High	Low	Low	Low	Low	Low
Paterno et al., 2025	Low	Low	Low	High	Low	Low	Low	Low	Low	Low
Piussi et al., 2023	Low	Low	Low	High	Low	Low	Low	High	High	High
Senorski et al., 2017	Low	Low	Low	High	Low	Low	High	Low	Low	High
Simonsson et al., 2024	Low	Low	Low	High	Low	Low	High	Low	Low	Low
Toole et al., 2017	Low	Low	Low	High	Low	Low	High	Low	Low	Low
Ueda et al., 2022	Low	Low	Low	High	High	High	Low	High	High	High
van Melick et al., 2022	Low	Low	Low	High	Low	Low	High	High	High	High
Webster et al., 2017	Low	Low	Low	High	High	Low	High	High	High	Low
Webster et al., 2018	Low	Low	Low	High	High	Low	High	Low	Low	Low
Webster et al., 2019a	Low	Low	Low	High	High	Low	High	High	High	High
Webster et al., 2019b	Low	Low	Low	High	Low	Low	High	High	High	High
Webster et al., 2020	Low	Low	Low	High	High	Low	Low	Low	Low	Low
Welling et al., 2020	Low	Low	Low	High	Low	Low	High	High	High	High
Zsidai et al., 2026	Low	Low	Low	High	Low	Low	High	Low	Low	Low

Supplementary Table 5. Modified Grading of Recommendations Assessment, Development and Evaluation (GRADE) assessment [a].

Hop test measure	Included studies: n	Study Limitations [b]	Inconsistency [c]	Indirectness [d]	Imprecision [e]	Reporting Bias [f]	Level of confidence	Summary of findings [g]
Return to sports								
Single-leg hop for distance								
LSI ≥ 90%	16	x	√	x	x	√	Low	▲
Greater absolute values of uninvolved limb	2	√	√	x	√	√	Inconsistent	◆
Greater absolute values of involved limb	2	√	√	x	√	√	Inconsistent	◆
Greater height-normalized values of uninvolved limb	1	x	NA	x	√	√	Limited	●
Greater height-normalized values of involved limb	3	x	√	x	x	√	Inconsistent	◆
Greater body mass-normalized values of uninvolved limb	1	x	NA	x	√	√	Limited	●
Greater body mass-normalized values of involved limb	1	x	NA	x	√	√	Limited	●
Greater side-to-side difference	1	x	NA	x	x	√	Limited	▲
Triple hop for distance								
LSI ≥ 90%	7	x	√	x	x	√	Low	●
Greater absolute values of uninvolved limb	1	√	NA	x	x	√	Limited	▲
Greater absolute values of involved limb	1	√	NA	x	x	√	Limited	▲
Greater height-normalized values of uninvolved limb	1	x	NA	x	x	√	Limited	▲
Greater height-normalized values of involved limb	2	√	√	x	√	√	Inconsistent	◆
Triple crossover hop for distance								
LSI ≥ 90%	7	x	√	x	x	√	Low	▲
Greater height-normalized values of uninvolved limb	1	x	NA	x	x	√	Limited	▲
Greater height-normalized values of involved limb	1	x	NA	x	x	√	Limited	▲
6-meter timed hop								
LSI ≥ 90%	4	x	√	x	x	√	Low	●
Greater absolute values of involved limb	1	√	NA	x	√	√	Limited	●

[a] no upgrading factors for all outcomes; [b] <30% from low risk of bias; [c] I^2>50% or wide variability in point estimates; [d] Wide pooled 95% CIs or few studies with small samples and imprecise estimates; [e] Heterogeneity substantially alters pooled estimate; [f] Evidence of reporting bias or <10 studies investigating the relationship; [g] ●: no association; ▲: hop test measure was associated with increased likelihood of RTS or decreased odds of reinjury; ▼: hop test measure was associated with decreased likelihood of RTS or increased odds of reinjury; ◆: inconsistent results; x: no limitations to downgrade; √: downgrade once; NA: not applicable.

Supplementary Table 5. Continue…

Hop test measure	Included studies: n	Study Limitations [b]	Inconsistency [c]	Indirectness [d]	Imprecision [e]	Reporting Bias [f]	Level of confidence	Summary of findings [g]
Side hop								
LSI ≥ 90%	2	x	x	x	√	√	Low	●
Greater absolute values of uninvolved limb	1	x	NA	x	√	√	Limited	▲
Greater absolute values of involved limb	1	x	NA	x	√	√	Limited	▲
Greater height-normalized values of uninvolved limb	1	x	NA	x	√	√	Limited	●
Greater height-normalized values of involved limb	1	x	NA	x	√	√	Limited	●
Balance front hop								
LSI ≥ 90%	1	x	NA	x	√	√	Limited	●
Balance side hop								
Greater absolute values of involved limb	2	x	x	x	√	√	Low	●
Bipedal drop vertical jump								
LSI ≥ 90%	2	x	x	x	√	√	Low	●
Bipodal countermovement jump								
LSI ≥ 90%	1	x	NA	x	√	√	Limited	●
Single-leg drop vertical jump								
LSI ≥ 90%	1	x	NA	x	x	√	Limited	▲
Single-leg vertical jump								
LSI ≥ 90%	1	x	x	x	x	√	Limited	▲
Greater body mass-normalized values of uninvolved limb	1	x	NA	x	√	√	Limited	●
Greater body mass-normalized values of involved limb	1	x	NA	x	√	√	Limited	●
Square hop								
LSI ≥ 90%	1	x	NA	x	√	√	Limited	●
Hop test battery								
3	x	√	x	x	√	Inconsistent	◆	

[a] no upgrading factors for all outcomes; [b] <30% from low risk of bias; [c] I^2>50% or wide variability in point estimates; [d] Wide pooled 95% CIs or few studies with small samples and imprecise estimates; [e] Heterogeneity substantially alters pooled estimate; [f] Evidence of reporting bias or <10 studies investigating the relationship; [g] ●: no association; ▲: hop test measure was associated with increased likelihood of RTS or decreased odds of reinjury; ▼: hop test measure was associated with decreased likelihood of RTS or increased odds of reinjury; ◆: inconsistent results; x: no limitations to downgrade; √: downgrade once; NA: not applicable.

Supplementary Table 5. Continue…

Hop test measure	Included studies: n	Study Limitations [b]	Inconsistency [c]	Indirectness [d]	Imprecision [e]	Reporting Bias [f]	Level of confidence	Summary of findings [g]
			Reinjury					
			Single-leg hop for distance					
LSI ≥ 90%	16	x	x	x	√	x	Moderate	●
Greater absolute values of uninvolved limb	2	x	x	x	√	√	Low	●
Greater absolute values of involved limb	3	x	x	x	√	√	Low	●
Greater height-normalized values of uninvolved limb	2	x	x	x	√	√	Low	●
Greater height-normalized values of involved limb	5	x	x	x	√	√	Low	●
			Triple hop for distance					
LSI ≥ 90%	9	x	x	x	x	√	Moderate	▼
Greater absolute values of uninvolved limb	2	√	x	x	√	√	Very low	●
Greater absolute values of involved limb	2	√	x	x	√	√	Very low	●
Greater height-normalized values of uninvolved limb	2	x	√	x	√	√	Inconsistent	◆
Greater height-normalized values of involved limb	3	x	√	x	√	√	Inconsistent	◆
			Triple crossover hop for distance					
LSI ≥ 90%	7	x	x	x	√	√	Low	●
Greater height-normalized values of uninvolved limb	1	x	NA	x	√	√	Limited	●
Greater height-normalized values of involved limb	1	x	NA	x	√	√	Limited	●
			6-meter timed hop					
LSI ≥ 90%	5	x	x	x	√	√	Low	●
Greater absolute values of involved limb	1	√	NA	x	√	√	Limited	●
			Side hop					
LSI ≥ 90%	3	x	x	x	x	√	Moderate	●
Greater absolute values of uninvolved limb	3	x	√	x	x	√	Inconsistent	◆
Greater absolute values of involved limb	3	x	√	x	x	√	Inconsistent	◆
Greater height-normalized values of uninvolved limb	1	x	NA	x	x	√	Limited	▼
Greater height-normalized values of involved limb	1	x	NA	x	x	√	Limited	▼

[a] no upgrading factors for all outcomes; [b] <30% from low risk of bias; [c] I^2>50% or wide variability in point estimates; [d] Wide pooled 95% CIs or few studies with small samples and imprecise estimates; [e] Heterogeneity substantially alters pooled estimate; [f] Evidence of reporting bias or <10 studies investigating the relationship; [g] ●: no association; ▲: hop test measure was associated with increased likelihood of RTS or decreased odds of reinjury; ▼: hop test measure was associated with decreased likelihood of RTS or increased odds of reinjury; ◆: inconsistent results; x: no limitations to downgrade; √: downgrade once; NA: not applicable.

Supplementary Table 5. **Continue…**

Hop test measure	Included studies: n	Study Limitations [b]	Inconsistency [c]	Indirectness [d]	Imprecision [e]	Reporting Bias [f]	Level of confidence	Summary of findings [g]
5-jump								
Greater absolute values of both limbs	1	x	NA	x	x	√	Limited	▼
Greater height-normalized values of both limbs	1	x	NA	x	x	√	Limited	▼
Single-leg countermovement jump								
LSI ≥ 90%	1	x	NA	x	√	√	Limited	●
Greater absolute values of involved limb	1	x	NA	x	x	√	Limited	●
Single-leg drop jump								
LSI ≥ 90%	1	x	NA	x	√	√	Limited	●
Greater absolute values of involved limb	2	x	x	x	√	√	Low	●
Greater absolute values of uninvolved limb	1	x	NA	x	√	√	Limited	●
Single-leg vertical jump								
LSI ≥ 90%	3	x	√	x	x	√	Low	●
Greater height-normalized values of uninvolved limb	1	x	NA	x	√	√	Limited	●
Greater height-normalized values of involved limb	1	x	NA	x	√	√	Limited	●
20-m timed hop								
LSI ≥ 90%	1	√	NA	x	√	√	Limited	●
Greater absolute values of uninvolved limb	1	√	NA	x	√	√	Limited	●
Greater absolute values of involved limb	1	√	NA	x	√	√	Limited	●
20-meter timed crossover hop								
LSI ≥ 90%	1	√	NA	x	√	√	Limited	●
Greater absolute values of uninvolved limb	1	√	NA	x	√	√	Limited	●
Greater absolute values of involved limb	1	√	NA	x	√	√	Limited	●
Hop test battery								
LSI ≥ 90%	5	√	x	x	x	√	Low	●
Greater absolute values of uninvolved limb	1	√	NA	x	√	√	Limited	●
Greater absolute values of involved limb	1	√	NA	x	√	√	Limited	●

[a] no upgrading factors for all outcomes; [b] <30% from low risk of bias; [c] I^2>50% or wide variability in point estimates; [d] Wide pooled 95% CIs or few studies with small samples and imprecise estimates; [e] Heterogeneity substantially alters pooled estimate; [f] Evidence of reporting bias or <10 studies investigating the relationship; [g] ●: no association; ▲: hop test measure was associated with increased likelihood of RTS or decreased odds of reinjury; ▼: hop test measure was associated with decreased likelihood of RTS or increased odds of reinjury; ◆: inconsistent results; x: no limitations to downgrade; √: downgrade once; NA: not applicable.

Supplementary Table 5. Continue…

Hop test measure	Included studies: n	Study Limitations [b]	Inconsistency [c]	Indirectness [d]	Imprecision [e]	Reporting Bias [f]	Level of confidence	Summary of findings [g]
Ipsilateral graft rupture								
Single-leg hop for distance								
LSI ≥ 90%	1	x	NA	x	√	√	Limited	●
Triple hop for distance								
LSI ≥ 90%	1	x	NA	x	√	√	Limited	●
Triple crossover hop for distance								
LSI ≥ 90%	2	x	x	x	√	√	Low	●
6-meter timed hop								
LSI ≥ 90%	1	x	NA	x	√	√	Limited	●
Contralateral ACL injury								
Single-leg hop for distance								
LSI ≥ 90%	1	x	NA	x	√	√	Limited	●
Triple hop for distance								
LSI ≥ 90%	1	x	NA	x	√	√	Limited	●
Triple crossover hop for distance								
LSI ≥ 90%	2	x	x	x	√	√	Low	●
6-meter timed hop								
LSI ≥ 90%	1	x	NA	x	√	√	Limited	●

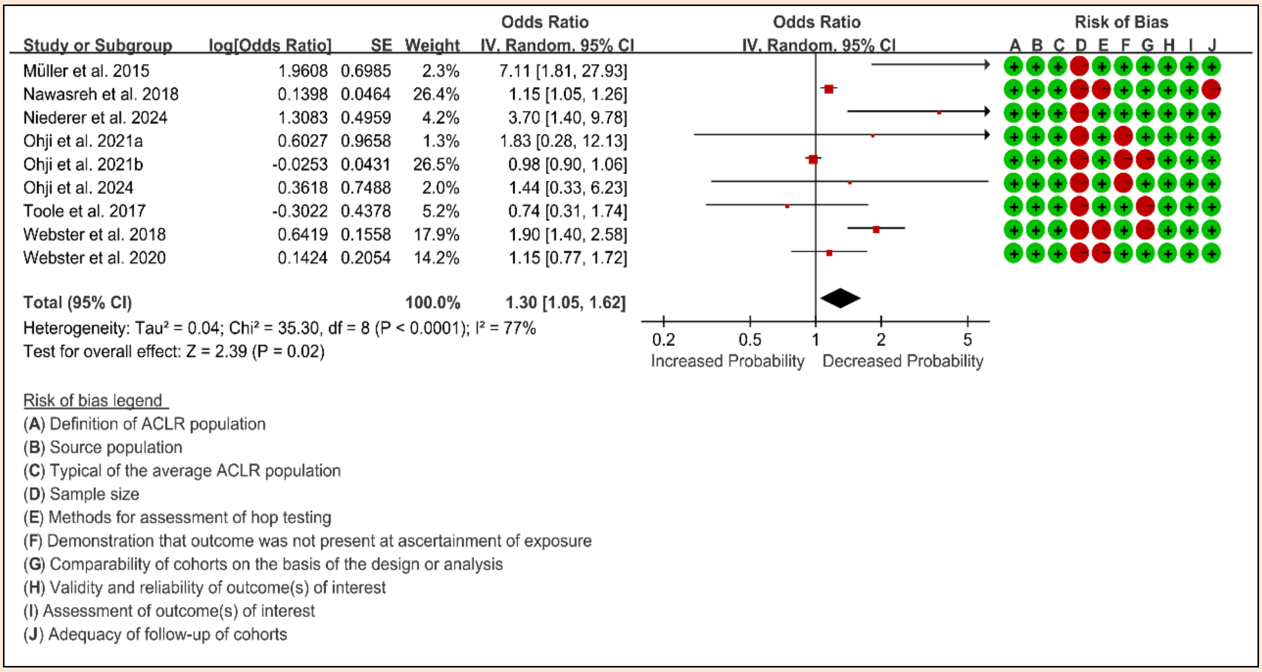
[a] no upgrading factors for all outcomes; [b] <30% from low risk of bias; [c] I^2>50% or wide variability in point estimates; [d] Wide pooled 95% CIs or few studies with small samples and imprecise estimates; [e] Heterogeneity substantially alters pooled estimate; [f] Evidence of reporting bias or <10 studies investigating the relationship; [g] ●: no association; ▲: hop test measure was associated with increased likelihood of RTS or decreased odds of reinjury; ▼: hop test measure was associated with decreased likelihood of RTS or increased odds of reinjury; ◆: inconsistent results; x: no limitations to downgrade; √: downgrade once; NA: not applicable.

Supplementary Table 6. Meta-regression results for the association between LSI ≥ 90% in single-leg hop for distance and return to sports

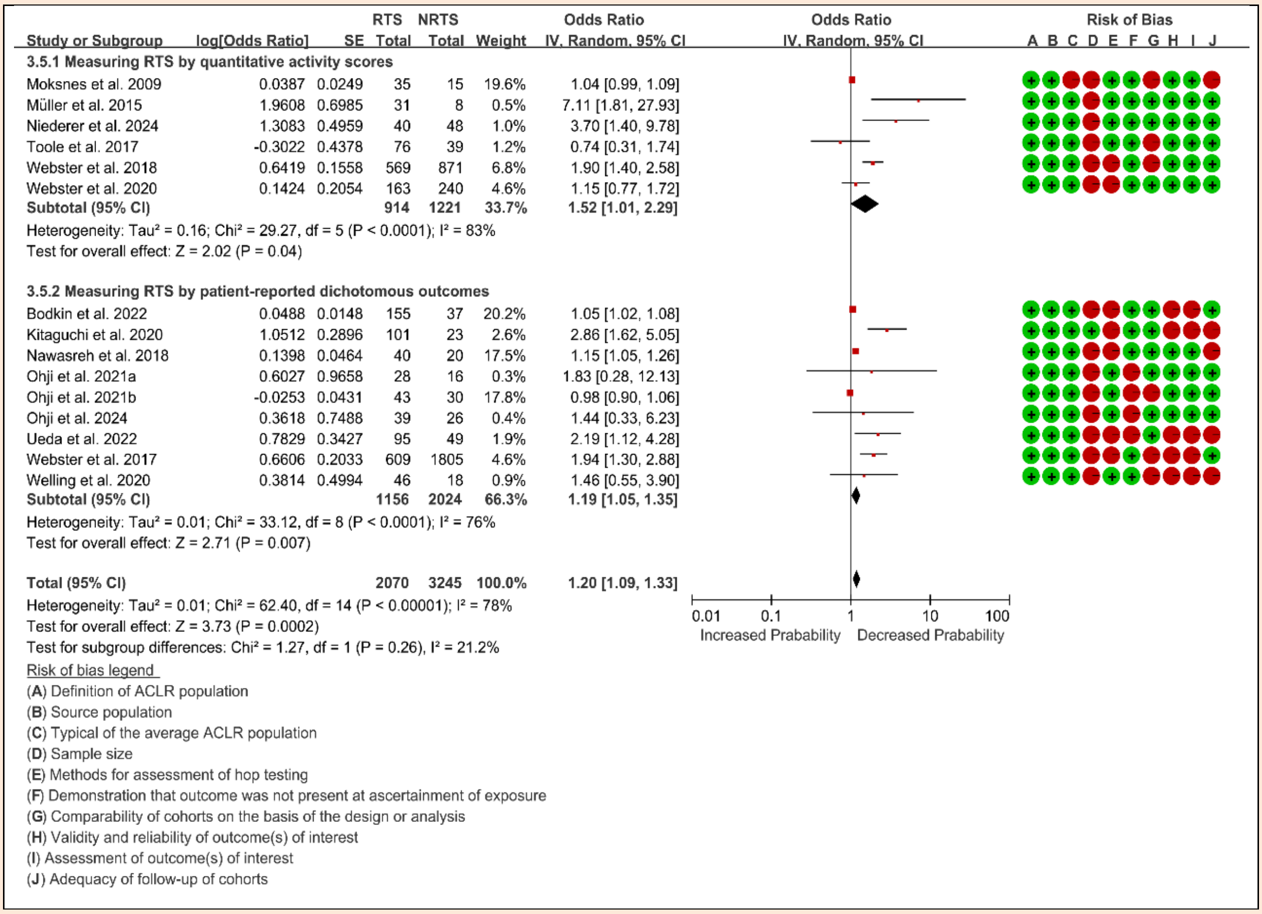
Variable(s)	Residual I^2	R^2	P value (model)	Coefficient (95% CI)		Standard error	P value (variable)
Female percentage	82.00	0.00	0.176	-0.003 (-0.008, 0.002)		0.002	0.175
HT graft proportion	79.17	0.00	0.262	0.003 (-0.002, 0.008)		0.002	0.262
Meniscus (with or without)	78.58	0.00	0.325	-0.134 (-0.418, 0.149)		0.131	0.325
Timing of testing (month)	79.16	0.00	0.548	0.009 (-0.022, 0.040)		0.014	0.548
Follow-up duration (month)	79.17	0.00	0.070	-0.023 (-0.047, 0.002)		0.011	0.070
HT graft proportion + meniscus	72.34	0.00	0.068	HT graft proportion	0.006 (0.001, 0.012)	0.003	0.037*
				Meniscus	-0.341 (-0.665, -0.017)	0.149	0.041*
HT graft proportion + timing of testing	80.77	0.00	0.655	HT graft proportion	0.003 (-0.004, 0.010)	0.003	0.433
				Timing of testing	0.003 (-0.049, 0.055)	0.024	0.899
HT graft proportion + follow-up duration	80.76	0.00	0.172	HT graft proportion	-0.002 (-0.010, 0.006)	0.004	0.630
				Follow-up duration	-0.032 (-0.073, 0.008)	0.019	0.109
Meniscus + timing of testing	80.17	0.00	0.636	Meniscus	-0.134 (-0.485, 0.217)	0.161	0.422
				Timing of testing	0.011 (-0.034, 0.057)	0.021	0.593
Meniscus + follow-up duration	65.83	0.00	0.006*	Meniscus	-0.520 (-0.833, -0.208)	0.144	0.003*
				Follow-up duration	-0.047 (-0.074, -0.021)	0.012	0.002*
Timing of testing + follow-up duration	80.76	0.00	0.192	Timing of testing	0.004 (-0.042, 0.050)	0.021	0.849
				Follow-up duration	-0.027 (-0.058, 0.004)	0.014	0.084

Supplementary Table 7. Sensitivity analysis using the leave-one-out method in the outcome of the association between achieving LSI ≥90% in single-leg hop for distance and return to sports.

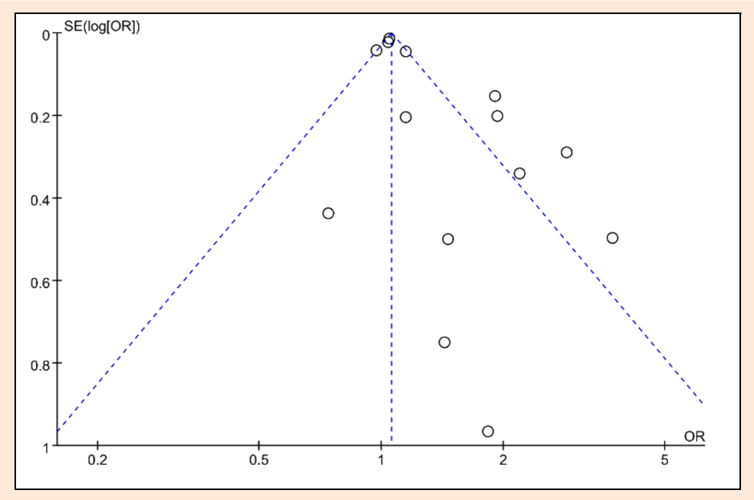
Excluded study	Participants	OR (95% CI), P value	Heterogeneity	Finding without this study
None (15 studies)	**5315**	**1.20 (1.09, 1.33), P < 0.01**	**I^2 = 78%, P < 0.01**	**--**
Bodkin et al., 2022	5123	1.35 (1.16, 1.57), P < 0.01	I^2 = 79%, P < 0.01	**No change**
Kitaguchi et al., 2020	5191	1.16 (1.06, 1.27), P < 0.01	I^2 = 74%, P < 0.01	**No change**
Moksnes et al., 2009	5265	1.33 (1.16, 1.53), P < 0.01	I^2 = 79%, P < 0.01	**No change**
Müller et al., 2015	5276	1.18 (1.08, 1.30), P < 0.01	I^2 = 76%, P < 0.01	**No change**
Nawasreh et al., 2018	5255	1.23 (1.10, 1.38), P < 0.01	I^2 = 78%, P < 0.01	**No change**
Niederer et al., 2024	5227	1.18 (1.08, 1.30), P < 0.01	I^2 = 77%, P < 0.01	**No change**
Ohji et al., 2021a	5271	1.20 (1.09, 1.33), P < 0.01	I^2 = 79%, P < 0.01	**No change**
Ohji et al., 2021b	5242	1.28 (1.14, 1.43), P < 0.01	I^2 = 78%, P < 0.01	**No change**
Ohji et al., 2024	5250	1.20 (1.09, 1.33), P < 0.01	I^2 = 79%, P < 0.01	**No change**
Toole et al., 2017	5200	1.21 (1.10, 1.34), P < 0.01	I^2 = 79%, P < 0.01	**No change**
Ueda et al., 2022	5171	1.18 (1.08, 1.30), P < 0.01	I^2 = 78%, P < 0.01	**No change**
Webster et al., 2017	2901	1.16 (1.06, 1.28), P < 0.01	I^2 = 76%, P < 0.01	**No change**
Webster et al., 2018	3875	1.14 (1.04, 1.25), P < 0.01	I^2 = 73%, P < 0.01	**No change**
Webster et al., 2020	4912	1.21 (1.09, 1.34), P < 0.01	I^2 = 79%, P < 0.01	**No change**
Welling et al., 2020	5251	1.20 (1.09, 1.33), P < 0.01	I^2 = 79%, P < 0.01	**No change**



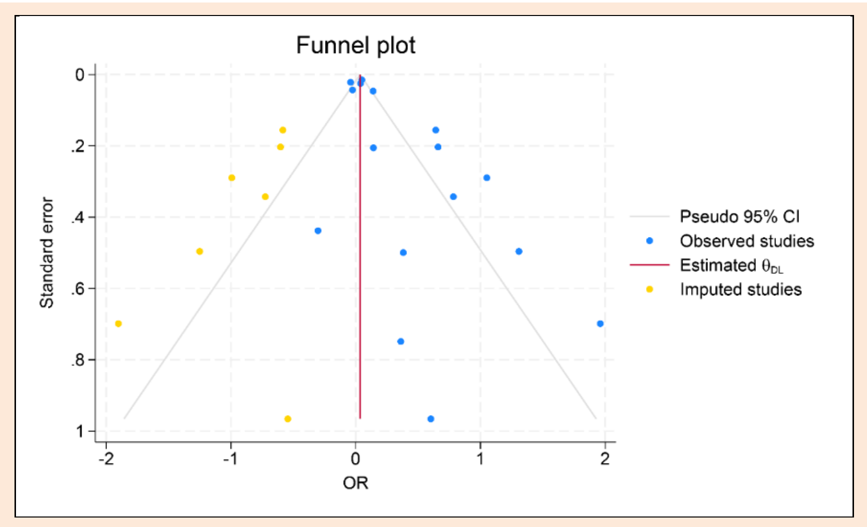
Supplementary Figure 1. **Forest plot displaying associations between achieving LSI (limb symmetry index) ≥ 90% in single-leg hop for distance by dropping studies with a high risk of bias, and quality assessment of each study using modified Newcastle-Ottawa Scale.**



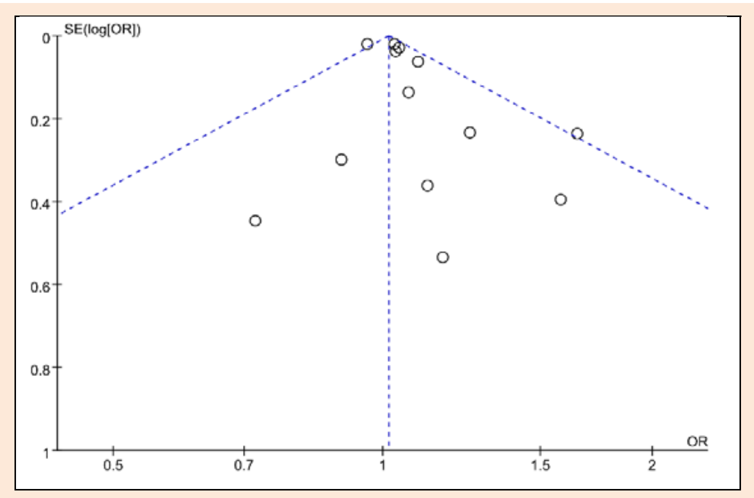
Supplementary Figure 2. **Forest plot displaying subgroup analyses of measuring RTS by quantitative activity scores and patient-reported dichotomous outcomes in association between achieving LSI (limb symmetry index) ≥ 90% in sin-gle-leg hop for distance (SLHD) and RTS (return to sports), and quality assessment of each study using modified Newcastle-Ottawa Scale**



Supplementary Figure 3. Funnel plot for association of LSI (Limb Symmetry Index) ≥ 90% in single-leg hop for distance test and RTS (return to sports) likelihood.



Supplementary Figure 4. The funnel plot with trim and fill imputation for association of LSI (Limb Symmetry Index) ≥ 90% in single-leg hop for distance test and RTS (return to sports) likelihood.



Supplementary Figure 5. Funnel plot for association of LSI (Limb Symmetry Index) ≥ 90% in single-leg hop for distance test and reinjury risk.