Title: The Effect of Core Stability Exercises on Agility Performance in Young Athletes: A Systematic Review and Meta-Analysis

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To appear in: ***Physical Treatments***

Received date: 2026/03/31

Revised date: 2026/05/18

Accepted date: 2026/05/19

First Online Published: 2026/06/23

Please cite this article as:

Ebrahimi E, Soltani F, Nourbakhsh SA, Masoumi F, Bahiraei S, Khosravi M. The Effect of Core Stability Exercises on Agility Performance in Young Athletes: A Systematic Review and Meta-Analysis. ***Physical Treatments.*** Forthcoming 2026. DOI: http://dx.doi.org/10.32598/ptj.2026.660.2

DOI: http://dx.doi.org/10.32598/ptj.2026.660.2

Abstract

Purpose: Agility underpins performance in youth sports requiring rapid directional changes, yet inconsistencies in primary studies leave the effects of core stability exercises (CSE) on agility performance in young athletes unresolved. Here, we quantify the effects of CSE on agility performance in young athletes through a systematic review and meta-analysis.

Methods: This PRISMA-compliant review (PROSPERO: CRD420261295923) searched PubMed, Scopus, Web of Science, and Google Scholar from inception to January 2026. Randomized and quasi-experimental trials evaluating CSE versus controls in athletes aged 10-24 years were included. Study quality was assessed using Joanna Briggs Institute checklists; random-effects meta-analysis was performed with Comprehensive Meta-Analysis software, evaluating heterogeneity (I^2, Q-test) and publication bias (Egger's test).

Results: After searching the mentioned databases, 204 articles (n=731 partcipants) were found, predominantly quasi-experimental with moderate-to-high quality. CSE significantly improved agility versus controls (standardized mean difference = -0.878, 95% CI -1.120 to -0.636, $P < 0.001$). Heterogeneity was moderate (I^2=59.83%, $P < 0.001$); sensitivity analysis excluding two low-quality studies reduced heterogeneity (I^2=30.97%, P=0.072) without altering significance (95% CI -0.950 to -0.577, $P < 0.001$). Egger's test indicated publication bias (P=0.001), but trim-and-fill adjustment (imputing 6 studies) confirmed robustness.

Conclusions: This meta-analysis demonstrates that CSE enhances agility performance in young athletes, addressing prior inconsistent findings in the literature, where studies have reported small, non-significant, or variable effects on agility and change-of-direction performance.

Keywords: Agility, Core Stability, Young Athletes, Sports Performance

Highlights:

- CSE significantly improved agility in youth athletes versus controls.
- Heterogeneity decreased after excluding low-quality studies.
- Agility improvements remained significant after sensitivity analysis.

Plain Language Summary:

This study looked at whether exercises that strengthen the body's core can help young athletes move more quickly and change direction faster. These "core stability exercises" are often recommended by coaches and trainers, but past research has not always agreed on how well they work. To provide a clearer answer, we gathered and analyzed results from many different studies in athletes aged 10 to 24. Across all the studies combined, young athletes who performed core stability exercises improved their agility more than those who did not. For coaches, trainers, parents, and young athletes, this research provides clear evidence that adding structured core exercises to regular training programs can boost athletic movement skills. This makes core stability exercises a simple, low-cost, and widely accessible tool to support healthy and effective athletic development.

Introduction

Young sport performance is shaped by physiological and motor-control factors, reflecting sport-specific motor-skill proficiency [1]. Regular physical activity corroborates motor development and physical fitness, and the World Health Organization recommends a minimum of 60 minutes of daily moderate-to-vigorous activity for individuals aged 10–24 [2]. During adolescence and youth, rapid neuromuscular and cognitive maturation heightens sensitivity to training stimuli, making this period critical for the development of physical performance [3]. Consequently, optimizing physical performance while supporting healthy development is a primary objective for coaches, practitioners, and sport scientists [4]. Among the physical qualities supporting youth sport performance, agility plays a pivotal role, especially in court-based sports where rapid changes of direction, acceleration, and deceleration occur repeatedly under time-pressured conditions [5, 6]. Effective agility relies on precise neuromuscular coordination and underpins motor function, the mastery of complex techniques, and injury prevention [7]. To enhance these skills, athletes commonly engage in various training methods, such as plyometric [8] and core stability exercises [9].

The core musculature comprises a functional muscular corset formed by the abdominal muscles anteriorly, the erector spinae and gluteal muscles posteriorly, the diaphragm superiorly, and the pelvic floor and hip girdle muscles inferiorly [10]. Together, these muscles provide dynamic stabilization of the spine and trunk during sport-specific movements involving the upper and lower extremities, such as jumping, throwing, and rapid changes of direction [11, 12]. Core stability is commonly conceptualized through the principle of proximal stability for distal mobility, whereby effective control of the trunk and pelvis facilitates efficient force production and transmission to the distal segments during athletic tasks [13]. Core stability exercises (CSE) have been shown to enhance athletic performance in various sports [14, 15], such as Kahraman et al. (2025) found improvements in agility and jumping performance in female badminton players [16]. In addition, studies have reported that CSE improved agility, ball-kicking accuracy, and balance [17, 18]. Despite the well-documented benefits of CSE, several studies have reported no effects on agility performance. Sever and Zorba (2018) and Prieske et al. (2016) observed no improvements in agility following CSE in football players [19, 20]. This inconsistency in findings may be attributable to substantial heterogeneity across studies, including differences in participant sport type, training duration, exercise selection, and agility assessment tools. Consequently, despite the growing body of primary research, it remains unclear whether core stability exercises produce a meaningful effect on agility performance in youth athletes. To date, no comprehensive meta-analysis has systematically quantified the magnitude of CSE's effects on agility. Addressing this gap is particularly important, as adolescence is a critical window for neuromuscular development and performance optimization. Therefore, a meta-analytic approach is warranted to resolve existing controversy, provide pooled effect estimates, and clarify the role of core stability exercises in enhancing agility performance among youth athletes.

Methods

This meta-analysis review study was registered prospectively in PROSPERO under the number CRD420261295923

Search strategy and keywords

This study used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [21]. All pertinent studies were retrieved through a structured search strategy. A comprehensive literature search was performed across three major academic databases, Scopus, Web of Science, and PubMed, covering all records available from their inception through January 2026. Google Scholar served as an additional resource to capture any relevant studies that may have been missed by the primary database search. Furthermore, the reference lists of identified papers were thoroughly examined by two reviewers working independently (E.E. and M.KH.) to uncover any additional eligible literature, with expert consultation provided by S.B. in the relevant field.

The following keyword combinations were used with the help of AND and OR operators as follows: (“core stability” OR “core training” OR “core strength” OR “core exercise*” OR “trunk training” OR “trunk strength” OR “trunk exercise*” OR “lumbopelvic stability” OR “trunk stabilization”) AND (“agility” OR “change of direction” OR “change-of-direction” OR “reactive agility”) AND (“athlete*” OR “player*” OR “sport*”) AND (“youth” OR “adolescent*” OR “young athlete*” OR “teen*”).

Inclusion and exclusion criteria

The study was designed based on the PICOS (Population, Intervention, Comparison, Outcomes, and Study) framework [22], including:

- Population (P): Young people aged 10-24 years, participating in one sport.
- Intervention (I): Trunk-focused (core stability exercises), lumbar, and hip-related strengthening approaches.
- Comparison (C): non-trunk-specific or conventional therapy or usual care.
- Outcomes (O): Agility.
- Study design (S): Quasi-experimental or randomized controlled trials (RCTs).

Moreover, eligible studies published in English in peer-reviewed journals were included up to the end of the search period (January 2026). The following exclusion criteria were implemented: 1) Focused on passive interventions; 2) Involved surgical procedures; 3) Focused on water-based or alternative exercise therapies; 4) Did not report sufficient statistical data for analysis; 5) Studies were published as conferences, papers, abstracts, and unpublished dissertations.

Study selection

Two independent reviewers (E.E. and M.KH.) separately assessed article titles and abstracts for eligibility based on predefined inclusion criteria and in accordance with the PRISMA guidelines, using a uniform Excel-based data extraction form [23]. The supervising author addressed and assessed discrepancies between the researchers (S.B.). Their searched records were imported into EndNote 20. This software was also used to remove duplicate articles.

Data extraction and quality assessment

Data were independently gathered by each reviewer using a uniform Excel-based extraction form, after which their results were cross-checked to assess consistency. Any disagreements or discrepancies that arose between the two reviewers were resolved through consultation with the supervising author (S.B.). The following key variables were systematically retrieved from each included study: the first author's name, publication year, study design, sample size, participant characteristics (encompassing age, sex, and index measurements), the primary data collection methods and instruments employed, and the most noteworthy findings reported. Two researchers (F.S., SA.N.) employed the Joanna Briggs Institute (JBI) Critical Appraisal tools [24] to evaluate the potential for bias, selecting the specific tool according to the research design included in each study. The level of agreement between evaluators was perfect, with a Kappa coefficient of 1. During the quality assessment process, a study is rated low quality if six or fewer of the nine questions (for quasi-experimental studies) are answered with “Yes”.

Data analysis

We used Comprehensive Meta-Analysis (CMA) software version 4.0 (Biostat Inc., Englewood, New Jersey) for statistical evaluation. From the eligible studies, we extracted the mean and standard deviation of pre- and post-tests (or mean differences), sample sizes, and P-values. Effect sizes were calculated as standardized mean differences (SMD) with 95% confidence intervals (CI). Using SMD made it possible to place all outcomes on a comparable scale. To account for small sample bias, Hedges’ g correction was applied. For interpretation, SMD thresholds of <0.2, 0.2–0.5, 0.5–0.8, and >0.8 were considered to indicate trivial, small, medium, and large effects, respectively [25]. Data heterogeneity was assessed using the Q-test and the I^2 statistic, with I^2 values representing the percentage of total variation due to heterogeneity. I^2 values of 25%, 50%, and 75% were considered to represent low, moderate, and high heterogeneity, respectively [26]. Publication bias was evaluated with Egger’s regression test, where P-values <0.05 were considered significant.

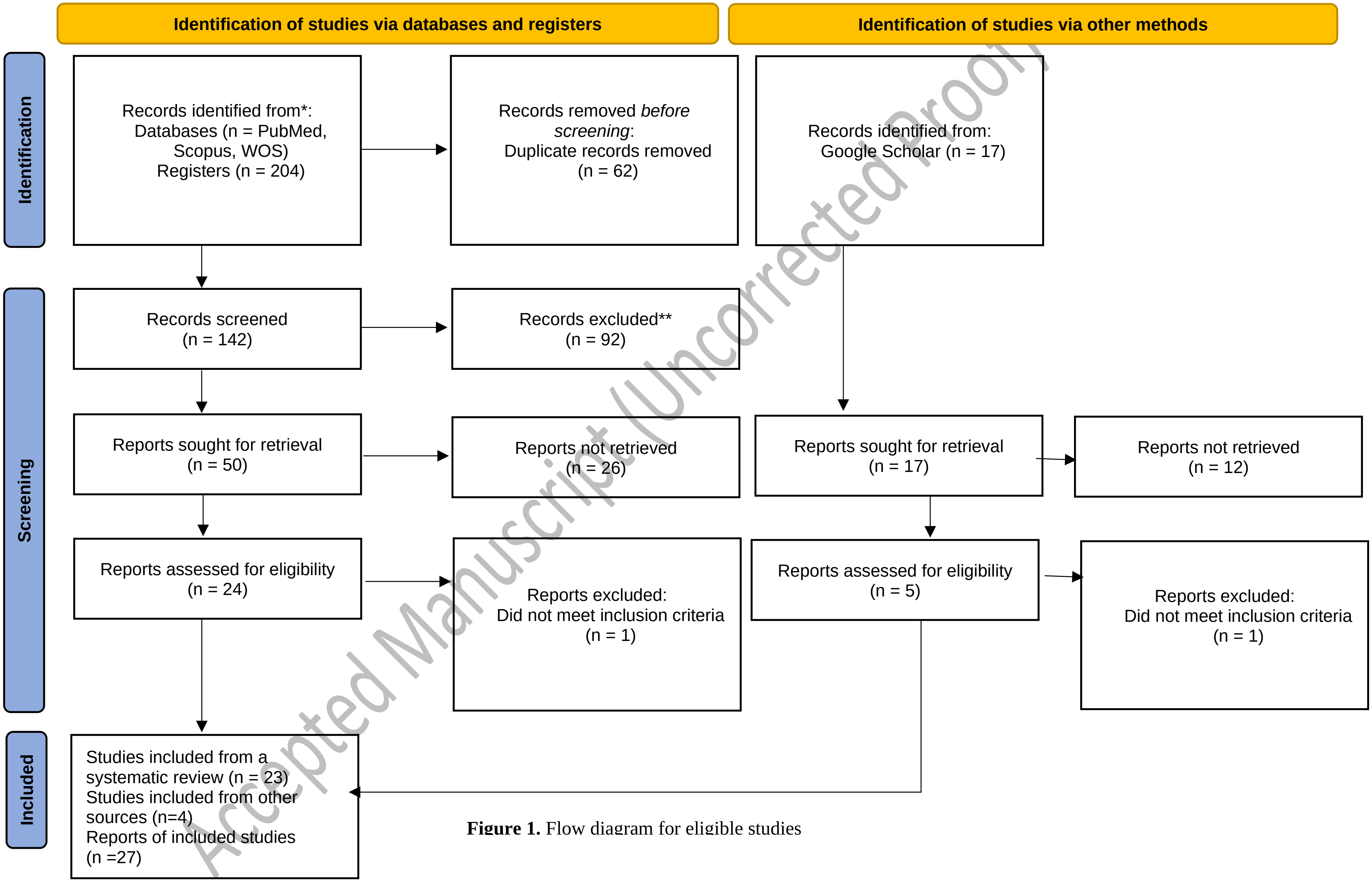


Figure 1. Flow diagram for eligible studies

Results

An initial search across the Pubmed, Scopus, and Web of Scicence yielded 204 records (Figure 1). These references were imported into EndNote, where duplicate entries were identified and removed, leaving 142 unique articles. After reviewing the abstracts and titles, 50 articles were selected for further analysis, while the rest were excluded. Full-text assessment was subsequently performed on 24 articles, from which 23 met the predefined inclusion criteria. In addition, four relevant studies identified through Google Scholar were included, bringing the final number to 27.

Study characteristics

The included studies were published between 2016 and 2025 and comprised 27 studies evaluating the effects of CSE on agility performance (Table 1). Most studies employed a quasi-experimental design, with four RCTs [17, 27-29]. Collectively, the studies involved more than 700 participants, predominantly adolescents and young adults, with sample sizes ranging from 16 to 61 individuals. Participants were primarily male, although several studies included female athletes [16, 30, 31] or mixed-sex samples [27, 32]. The populations investigated represented a wide range of sports, including soccer [17, 19, 28-30, 33-42], basketball [32, 43, 44], tennis [1, 45, 46], badminton [16, 47], volleyball [31], karate [27], swimming [48], and running [49]. Intervention durations varied from 3 weeks to 12 weeks, with most studies implementing CSE lasting 6–8 weeks [19, 27-36, 38, 40, 42, 43, 45, 47-49]; one study extended the intervention period to 3 months [37]. Agility outcomes were assessed using a variety of validated field-based tests, most frequently the Illinois Agility Test [17, 30, 33, 35-39, 42, 47, 49], 5–10–5 Shuttle Test [1, 16, 19, 31, 32, 34, 40, 43, 45, 48], and Pro-Agility (change-of-direction) tests [27], along with other measures such as the Arrowhead [29], T-test [44, 46], Zigzag [28], and Square Test [41]. Overall, the majority of studies reported improvements in agility performance following CSE.

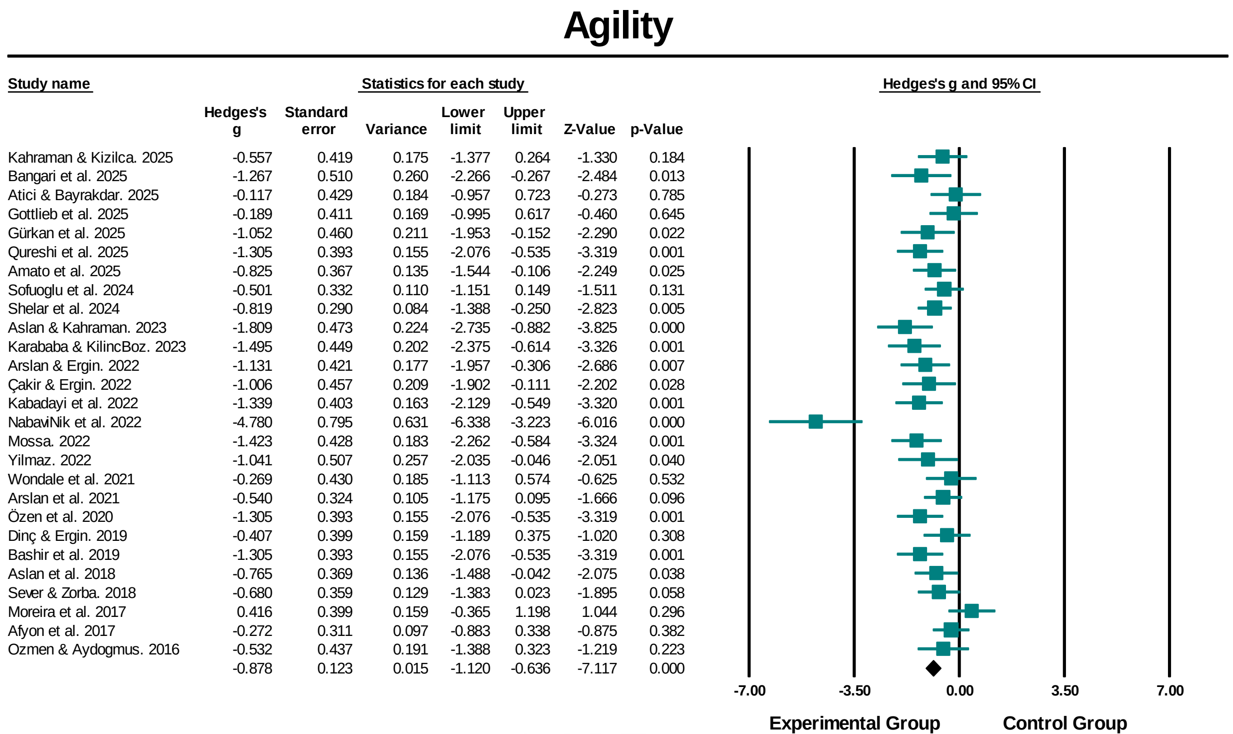
****Table 1****

Data synthesis

CSE effect on agility

27 studies examined the effect of CSE on agility in young athletes between the two experimental and control groups (Figure 2). A total of 731 participants took part in these studies. According to the meta-analyses, the results showed a significant difference between the two groups in the agility score (95% CI= -1.120 to -0.636, $P < 0.001$), indicating a greater increase in the experimental group. Also, the Q-test and I^2 test results showed significant heterogeneity across agility ($P < 0.001$, I^2= 59.83 %). Due to observed heterogeneity in the results, a sensitivity analysis was performed. A sensitivity analysis was conducted to explore sources of heterogeneity. This analysis showed that exclusion of two studies classified as low quality, Aslan & Kahraman (2023) and NabaviNik et al. (2022), did not alter the overall effect estimate (95% CI = -0.950 to -0.577, $P < 0.001$), but substantially reduced heterogeneity from moderate to low levels (I^2 = 30.97%, $P = 0.072$). Egger's test showed that publication bias was significant in agility ($P = 0.001$). The trim-

and-fill method was used to assess the potential effect of future studies on the results. The results showed that adding six hypothetical studies to the right side of the graph could not change the meta-analysis results (Figure 3).



Study name	Hedges's g	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Kahraman & Kizilca. 2025	-0.557	0.419	0.175	-1.377	0.264	-1.330	0.184
Bangari et al. 2025	-1.267	0.510	0.260	-2.266	-0.267	-2.484	0.013
Atici & Bayrakdar. 2025	-0.117	0.429	0.184	-0.957	0.723	-0.273	0.785
Gottlieb et al. 2025	-0.189	0.411	0.169	-0.995	0.617	-0.460	0.645
Gürkan et al. 2025	-1.052	0.460	0.211	-1.953	-0.152	-2.290	0.022
Qureshi et al. 2025	-1.305	0.393	0.155	-2.076	-0.535	-3.319	0.001
Amato et al. 2025	-0.825	0.367	0.135	-1.544	-0.106	-2.249	0.025
Sofuoglu et al. 2024	-0.501	0.332	0.110	-1.151	0.149	-1.511	0.131
Shelar et al. 2024	-0.819	0.290	0.084	-1.388	-0.250	-2.823	0.005
Aslan & Kahraman. 2023	-1.809	0.473	0.224	-2.735	-0.882	-3.825	0.000
Karababa & KilincBoz. 2023	-1.495	0.449	0.202	-2.375	-0.614	-3.326	0.001
Arslan & Ergin. 2022	-1.131	0.421	0.177	-1.957	-0.306	-2.686	0.007
Çakir & Ergin. 2022	-1.006	0.457	0.209	-1.902	-0.111	-2.202	0.028
Kabadayi et al. 2022	-1.339	0.403	0.163	-2.129	-0.549	-3.320	0.001
NabaviNik et al. 2022	-4.780	0.795	0.631	-6.338	-3.223	-6.016	0.000
Mossa. 2022	-1.423	0.428	0.183	-2.262	-0.584	-3.324	0.001
Yilmaz. 2022	-1.041	0.507	0.257	-2.035	-0.046	-2.051	0.040
Wondale et al. 2021	-0.269	0.430	0.185	-1.113	0.574	-0.625	0.532
Arslan et al. 2021	-0.540	0.324	0.105	-1.175	0.095	-1.666	0.096
Özen et al. 2020	-1.305	0.393	0.155	-2.076	-0.535	-3.319	0.001
Dinç & Ergin. 2019	-0.407	0.399	0.159	-1.189	0.375	-1.020	0.308
Bashir et al. 2019	-1.305	0.393	0.155	-2.076	-0.535	-3.319	0.001
Aslan et al. 2018	-0.765	0.369	0.136	-1.488	-0.042	-2.075	0.038
Sever & Zorba. 2018	-0.680	0.359	0.129	-1.383	0.023	-1.895	0.058
Moreira et al. 2017	0.416	0.399	0.159	-0.365	1.198	1.044	0.296
Afyon et al. 2017	-0.272	0.311	0.097	-0.883	0.338	-0.875	0.382
Ozmen & Aydogmus. 2016	-0.532	0.437	0.191	-1.388	0.323	-1.219	0.223
	-0.878	0.123	0.015	-1.120	-0.636	-7.117	0.000

Figure 2. Forest plot of Agility

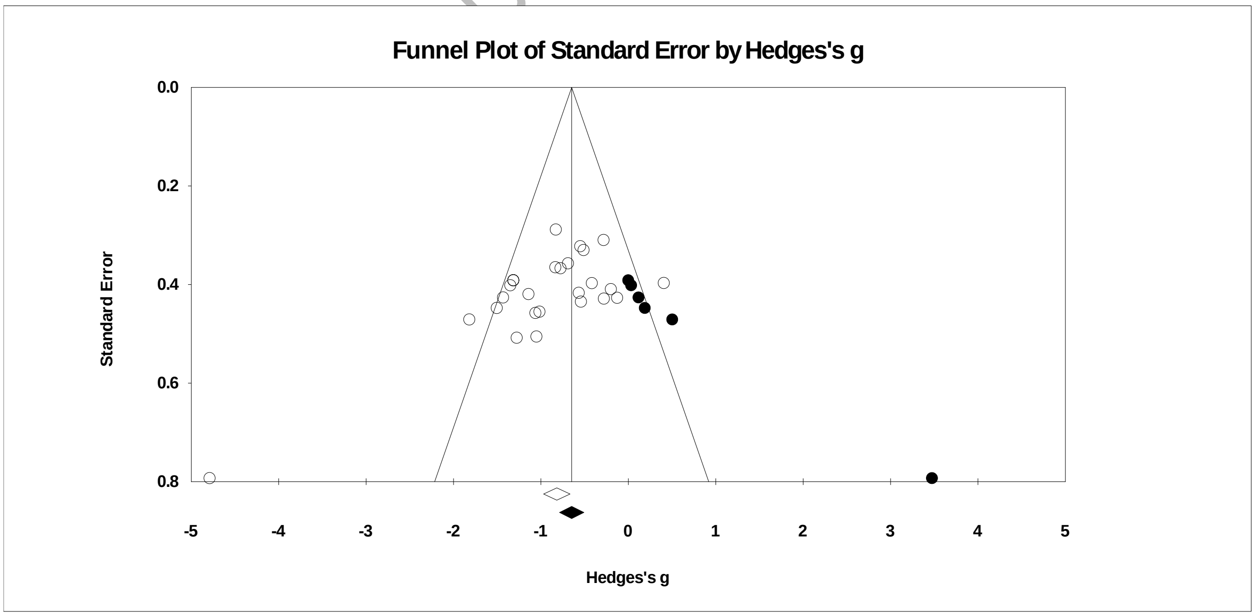


Figure 3. Funnel plot of Agility

Risk of bias

The methodological quality of the included studies was evaluated using the JBI Critical Appraisal Checklists appropriate for quasi-experimental studies and RCTs (Table 2). Among the quasi-experimental studies, overall quality scores ranged from 6 to 8 out of a possible 9, indicating generally moderate to high methodological quality. The majority of studies achieved scores of 7/9 or 8/9, reflecting a predominantly low to moderate risk of bias and consistent adherence to methodological standards, including baseline comparability of groups, reliable outcome measurement, and appropriate statistical analyses. No study achieved the maximum score, with the most frequently unmet criterion being Q8, related to completeness of follow-up, suggesting a recurrent risk of attrition bias across this study design. Two studies [35, 48] scored 6/9, indicating a comparatively higher risk of bias due to multiple unmet criteria, particularly incomplete follow-up and limitations in reporting participant retention. For RCTs, methodological quality scores were uniformly 10 out of 13, indicating moderate overall quality. While all RCTs demonstrated strengths in randomization, baseline comparability, outcome reliability, and statistical analysis, several domains related to blinding (participants, intervention providers, and outcome assessors) and identical treatment delivery were consistently unmet. Overall, despite recurrent challenges related to blinding and follow-up reporting, the included studies demonstrated acceptable methodological rigor. The predominance of moderate-to-high JBI scores supports the robustness of the evidence base, although findings should be interpreted with appropriate caution given the identified sources of bias.

****Table 2****

Discussion

This meta-analysis, synthesizing data from 27 randomized and quasi-experimental trials encompassing 731 young athletes aged 10–24 years, provides moderate-to-strong pooled evidence that core stability exercises (CSE) significantly improve agility performance relative to control conditions (SMD = -0.878, 95% CI -1.120 to -0.636, $P < 0.001$). The large effect size remained robust in sensitivity analyses that excluded two low-quality studies (SMD = -0.764, 95% CI -0.950 to -0.577, $P < 0.001$), which also reduced heterogeneity from moderate ($I^2 = 59.83\%$, $P < 0.001$) to low levels ($I^2 = 30.97\%$, $P = 0.072$). The marked drop in heterogeneity after excluding these two outliers likely stems from their lower methodological rigor, such as inadequate follow-up and potential confounding in protocols, highlighting how study quality influences pooled estimates. Although Egger's test suggested potential publication bias ($P = 0.001$), trim-and-fill adjustments, which imputed six hypothetical studies, did not alter the statistical significance or direction of the effect. However, the presence of funnel plot asymmetry and significant Egger's test suggests potential publication bias and/or small-study effects. Therefore, while the beneficial effect of CSE on agility is likely to be genuine, the magnitude of the pooled effect size may be overestimated and should be interpreted with caution.

The meta-analytic findings demonstrate consistent moderate-to-large improvements in agility across diverse athletic contexts, including soccer, basketball, tennis, badminton, volleyball, karate, swimming, and running. Interventions, typically lasting 6–8 weeks (range: 3–12 weeks) and involving predominantly male adolescents with sample sizes of 16–61 participants, were evaluated using established field tests such as the Illinois Agility Test, 5-10-5 Shuttle Test, Pro-Agility Test, T-Test, and Zigzag Test. This broad efficacy aligns with prior systematic reviews that have demonstrated the benefits of core training for skill-related fitness components, including agility, explosive power, speed, and balance, in soccer players and multi-sport athletes [14, 50]. However, recent meta-analyses on core/trunk training in athletes (often mixed ages or broader populations) report smaller or non-significant effects on change-of-direction (COD)/agility performance (SMD typically 0.10–0.75, frequently non-significant or moderate at best [51]; e.g., SMD = 0.10, 95% CI -0.56 to 0.76, $P = 0.69$ for COD in one comprehensive analysis, or medium but non-significant SMD ≈ -0.54, $P = 0.12$ in RCTs focused on sport-specific agility). In contrast to isolated studies reporting null effects (e.g., no agility gains in football players following CSE [9, 13, 19]), the pooled data indicate that such discrepancies arise from methodological heterogeneity, including variations in training protocols, durations, exercise selections, and assessment tools [35, 48]. The notably larger effect here may be driven by youth-specific neuromuscular plasticity, inclusion of quasi-experimental designs (higher risk of bias/inflation), and reliance on pre-planned COD tests rather than reactive/perceptual-cognitive assessments. The predominance of quasi-experimental designs (23/27 studies) with moderate-to-high methodological quality (JBI scores: 6–8/9 for quasi-experimental studies; 10/13 for RCTs) supports the generalizability of these outcomes, although recurrent limitations in blinding and follow-up require cautious interpretation.

Mechanistically, the agility enhancements associated with CSE can be attributed to improved lumbopelvic-hip complex stability, which facilitates efficient transmission of ground reaction forces during high-velocity tasks involving acceleration, deceleration, and directional changes [11, 13, 52]. Grounded in the principle of proximal stability enabling distal mobility, CSE strengthens the muscular corset (e.g., transversus abdominis, multifidus, and gluteal muscles) to minimize trunk sway and rotational instability, thereby optimizing center-of-mass control [10, 53, 54]. Empirical evidence includes studies of badminton players in which CSE produced significant gains in dynamic balance and Illinois Agility Test performance ($P < 0.001$) [16], reflecting refined feedforward neuromuscular activation in maturing youth systems [3]. Complementary improvements in related domains such as balance, sprint speed, and vertical jump height—further suggest indirect benefits to lower-limb kinetics, with core endurance exercises (e.g., planks) yielding post-intervention enhancements [14, 17]. These findings are corroborated by meta-analyses showing positive effects of core training on vertical and horizontal jumps (ES = 0.69–0.84), throwing velocity and distance (ES = 0.30–3.42), and balance (ES = 1.17), achieved through enhanced torso stiffness that reduces energy dissipation during dynamic movements [52, 55]. In soccer-specific contexts, CSE has been associated with concurrent improvements in power and dynamic balance (e.g., Star Excursion Balance Test gains of 8.79 cm, $P < 0.05$), with trunk endurance metrics (McGill tests) correlating with superior movement control [56]. While CSE provides foundational enhancements such as trunk stiffness and balance, direct transfer to agility , particularly reactive components ,may be limited without integration of sport-specific or perceptual elements, as evidenced by smaller effects in broader COD-focused syntheses.

The larger effects observed in youth athletes likely reflect heightened neuromuscular plasticity during adolescence, a developmental period characterized by rapid maturation and increased responsiveness to training stimuli [3, 4]. Meta-analyses of resistance and core programs in this population report moderate-to-large gains in strength and jump performance (SMD = 0.8–1.09), moderated by factors such as sex, training duration (>23 weeks), and intensity (80–89% 1RM) [57]. Integrative approaches combining CSE with neuromuscular training further enhance agility, coordination, and fatigue resistance while mitigating injury risk [7, 58]. Dose-response evidence suggests that minimal effective protocols involve 15 minutes per session, twice weekly for at least 4 weeks, with progressive intensification promoting transfer to sport-specific skills [59]. Comparatively, prior reviews of trunk-focused interventions report small-to-moderate effects on agility and speed (SMD = 0.58–0.75) in youth [60], whereas combined balance-plyometric regimens yield equivalent large effects on countermovement jumps, agility shuttles, and Y-Balance Test performance compared with agility-plyometric programs alone [61]. Core-specific syntheses in racket and field sports reinforce these benefits through optimized force channeling from the core to the extremities [62], although null or trivial effects in abbreviated protocols highlight the importance of adequate duration and intensity [63]. The present analysis advances the literature by providing agility-specific pooled estimates, distinguishing it from broader performance reviews.

Clinical Implications

From a practical perspective, the accessibility of CSE requiring minimal equipment renders it suitable for integration into school- or club-based programs, complementing plyometric training in 6–8-week cycles to prevent overload [8, 20]. Protocols of 15 minutes per session (twice weekly minimum) appear effective [17], though variability exists, and shorter sessions (≤30 minutes) sometimes yield superior COD adaptations in trunk training meta-analyses. Individualization by maturation stage and sport is recommended. Indirect injury prevention benefits are noteworthy, with CSE improving landing biomechanics (e.g., reduced peak vertical ground reaction forces and loading rates, $P < 0.05$) during single-leg drops and cutting maneuvers [35]. Incorporation of CSE into warm-ups has demonstrated gains in explosive power (12.85–18.45%), agility (-4.49%), and speed (-6.16%) among junior athletes. Coaches should prioritize progressive targeting of deep stabilizers, maturation-based stratification (e.g., via peak height velocity), and reactive agility drills to maximize ecological validity and competitive transfer [5, 6].

Limitations

Strengths of this meta-analysis include adherence to PRISMA guidelines, prospective PROSPERO registration (CRD420261295923), comprehensive searches up to January 2026, dual independent data extraction (Kappa = 1.0), and use of Comprehensive Meta-Analysis software with Hedges' g correction. JBI appraisals confirmed predominantly low-to-moderate risks of bias, primarily in blinding and follow-up domains. Nevertheless, limitations must be acknowledged. A key limitation of the present meta-analysis is the predominance of quasi-experimental designs (23 out of 27 studies), with only four RCTs included. While quasi-experimental studies provide valuable applied insights, they are inherently more susceptible to selection bias, residual confounding, and lack of allocation concealment, which may lead to systematic overestimation of intervention effects. Consequently, the large pooled effect size observed in this analysis (SMD = -0.878) should be interpreted with caution, as it may partially reflect design-related bias rather than true intervention efficacy. Although the included studies demonstrated moderate-to-high methodological quality based on JBI appraisal, important domains such as randomization, blinding, and control of confounders were frequently unmet.

Future Research Directions

Future research should prioritize high-quality RCTs with standardized reporting of intervention progression, participant maturation (e.g., peak height velocity), blinding procedures, and extended follow-up periods (≥12 weeks) to evaluate long-term retention, injury incidence, and transfer to competitive performance. Incorporation of reactive agility tests (e.g., video-based simulations) and comparator arms (e.g., CSE vs. plyometrics) would clarify differential effects, while moderator analyses by sex, maturation stage, and sport type could refine prescriptive recommendations. Longitudinal studies tracking outcomes into adulthood are essential to assess persistence.

Conclusion

In conclusion, this meta-analysis provides robust, bias-adjusted evidence that CSE substantially augments agility performance in youth athletes, underpinned by biomechanical and neuromuscular mechanisms potentiated by developmental plasticity. Effect magnitudes should be interpreted cautiously relative to broader core training syntheses showing smaller impacts on change-of-direction performance. These findings support the strategic incorporation of progressive CSE into youth athletic development programs to optimize multidirectional capabilities and potentially reduce injury risk, with implications for coaches, practitioners, and sport scientists. Nonetheless, full realization of these benefits depends on addressing methodological gaps in future rigorous trials.

Statements and Declarations

Funding: The authors declare that no funds, grants, or other support were received during the preparation of this manuscript.

Competing Interests: The authors have no relevant financial or non-financial interests to disclose.

Author Contributions: All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by [MKh], [SAN], and [FM]. The first draft of the manuscript was written by [EE], and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Data availability: The data that support the findings of this study are available on request from the corresponding author.

Ethics approval: Not applicable.

Consent to participate: Not applicable.

Consent to publish: Not applicable.

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Table 1. Demographic information from included studies

Study	Design	Participants	Gender (M/F)	Age	Sports	Experimental Intervention	Control Intervention	Agility Measured Index	Results
Kahraman & Kızılca. 2025 [16]	Quasi-experimental	22 Participants (EG: 11, CG: 11)	0/22	EG: 10.91±0.94 CG: 10.82±0.98	Badminton	4 Weeks of core exercises (two days per week)	Usual badminton training (two days per week)	5-10-5 Shuttle test	Improved agility after intervention (p=0.045)
Bangari et al. 2025 [1]	Quasi-experimental	17 Participants (EG: 8, CG: 9)	17/0	EG: 12.8±0.6 CG: 13.1±0.7	Tennis	12 Weeks of core exercises and plyometric (three sessions per week, including 5 sets × 5–8 reps)	Usual tennis training (three sessions per week)	5-10-5 Shuttle test	Improved agility after intervention (p=0.015)
Atici & Bayrakdar. 2025 [29]	RCT	20 Participants (EG: 10, CG: 10)	20/0	EG: 13.9±0.73 CG: 13.30±0.67	Soccer	8 Weeks of core exercises (three days a week for 30 minutes)	Usual soccer training (three days a week for 30 minutes)	Arrowhead agility test	Improved agility after intervention (p=0.024)
Gottlieb et al. 2025 [17]	RCT	22 Participants EG: 11, CG: 11)	22/0	EG: 13.0±1.01 CG: 13.0±1.01	Soccer	12 Weeks of core exercises (two 15–20 min-long training sessions weekly)	Ball movement training (two sessions per week)	Illinois Agility Test	Improved agility after intervention (p≤0.05)
Gürkan et al. 2025 [33]	Quasi-experimental	20 Participants (EG: 10, CG: 10)	20/0	EG: 11.70±0.47 CG: 11.70±0.47	Soccer	8 Weeks of core exercises (two sessions per week)	Usual soccer training (two sessions per week)	Illinois Agility Test	No significant improvement in the agility after intervention (p=0.112)

Qureshi et al. 2025 [30]	Quasi-experimental	30 Participants (EG: 15, CG: 15)	0/30	aged 18-24 years	Soccer	8 Weeks of core exercises (four sessions per week, 45 minutes per session)	Usual soccer training (four sessions per week)	Illinois Agility Test	Improved agility after intervention (P < 0.001)
Amato et al. 2025 [43]	Quasi-experimental	31 Participants (EG: 17, CG: 14)	31/0	EG: 14.88±1.90 CG: 14.71±2.27	Basketball	8 Weeks of core exercises (three times per week)	8 Weeks of mobility training (three times per week)	5-10-5 Shuttle test	No significant improvement in the agility after intervention (p=0.736)
Sofuoğlu et al. 2024 [34]	Quasi-experimental	36 Participants (EG: 19, CG: 17)	36/0	EG: 13.05±0.78 CG: 12.82±0.81	Soccer	8 Weeks of core exercises (three days a week)	Usual soccer training (three times per week)	5-10-5 Shuttle test	No significant improvement in the agility after intervention (p=0.211)
Shelar et al. 2024 [32]	Quasi-experimental	50 Participants (EG: 25, CG: 25)	25/25	EG: 22.65±1.46 CG: 20.75±2.40	Basketball	8 Weeks of core exercises (three times per week, including 40 minutes of main exercises)	Basketball-specific training (three times per week)	5-10-5 Shuttle test	Improved in the agility after the intervention (p≤0.05)
Aslan & Kahraman. 2023 [35]	Quasi-experimental	24 Participants (EG: 12, CG: 12)	24/0	EG: 12.16±0.83 CG: 12.25±0.62	Soccer	6 Weeks of core exercises (three days a week)	Usual soccer training (three times per week)	Illinois Agility Test	Improved in the agility after the intervention (p≤0.05)
Karababa & KilincBoz. 2023 [36]	Quasi-experimental	24 Participants (EG: 12, CG: 12)	24/0	EG: 15.17±0.71 CG: 14.92±0.66	Soccer	8 Weeks of core exercises (three days a week)	Usual soccer training (three times per week)	Illinois agility test	No significant improvement in the agility after intervention (p=0.517)

Çakir & Ergin. 2022 [31]	Quasi-experimental	20 Participants (EG: 10, CG: 10)	0/20	EG: 14.70±0.82 CG: 14.60±0.84	Volleyball	8 Weeks of core exercises (three days a week)	Usual volleyball training (three times per week)	5-10-5 Shuttle test	Improved in the agility after the intervention (p=0.003)
Arslan & Ergin. 2022 [45]	Quasi-experimental	25 Participants (EG: 11, CG: 14)	NA	EG: 12.90±0.94 CG: 11.98±1.38	Tennis	8 Weeks of core exercises (three days a week)	Usual tennis training (three times per week)	5-10-5 Shuttle test	Improved in the agility after the intervention (p=0.008)
Kabadayı et al. 2022 [27]	RCT	29 Participants (EG: 16, CG: 13)	12/17	EG: 12.75±0.77 CG: 13.0±0.91	Karate	8 Weeks of core exercises (three times per week)	Sport-specific program (three times per week)	Pro-agility (Change of direction)	No significant improvement in the agility after intervention (p=0.654)
NabaviNik et al. 2022 [48]	Quasi-experimental	24 Participants (EG: 12, CG: 12)	24/0	EG: 12.53±1.19 CG: 12.61±1.04	Swimming	6 Weeks of core exercise (three times per week)	Usual swimming training (three times per week)	Shuttle Run (4*9)	Improved in the agility after the intervention (p=0.001)
Mossa. 2022 [37]	Quasi-experimental	26 Participants (EG: 13. CG: 13)	NA	aged 14 years	Soccer	3 Months of core exercises (twice a week, for 30 to 35 minutes each day)	Usual soccer training (twice a week)	Illinois agility test	Improved in the agility after the intervention (p=0.001)
Yılmaz. 2022 [44]	Quasi-experimental	16 Participants (EG: 8, CG:8)	NA	EG: 13.29±1.96 CG: 13.29±1.96	Basketball	4 Weeks of core exercises (two days a week, 60 minutes a day)	Usual basketball training (two days a week)	Modified agility t-test	Improved in the agility after the intervention (p=0.045)
Wondale et al. 2021 [38]	Quasi-experimental	20 Participants (EG: 10, CG: 10)	20/0	EG: 15.90±0.31 CG: 15.90±0.31	Soccer	8 Weeks of core exercises (40-minute core strength training twice a week)	Usual soccer training (twice a week)	Illinois agility test	Improved in the agility after the intervention (p=0.001)

Arslan et al. 2021 [28]	RCT	38 Participants (EG: 20, CG: 18)	38/0	EG: 16.30±0.47 CG: 16.50±0.51	Soccer	6 Weeks of combined core strength and small-sided games training (three days a week)	Small-sided games (three days a week)	Zigzag agility test	Improved in the agility after the intervention (p≤0.05)
Özen et al. 2020 [39]	Quasi-experimental	30 Participants (EG: 15, CG: 15)	30/0	EG: 15.33±0.48 CG: 16.66±0.48	Soccer	3 Weeks of core exercises (two days a week for 3 weeks)	3 Weeks of plyometric training (two days a week)	Illinois agility test	Improved in the agility after the intervention (p=0.001)
Dinç & Ergin. 2019 [49]	Quasi-experimental	28 Participants (EG: 15, CG: 13)	NA	EG: 19.50±1.20 CG: 19.4±1.50	Running	8 Weeks of core exercises (three days a week)	Usual running training (three days a week)	Illinois agility test	Improved in the agility after the intervention (p=0.043)
Bashir et al. 2019 [46]	Quasi-experimental	30 Participants (EG: 15, CG: 15)	NA	EG: 15.20±0.41 CG: 15.53±1.6	Tennis	5 Weeks of core exercises (three times per week)	Usual tennis training (three days a week)	T-test	Improved in the agility after the intervention (p=0.001)
Aslan et al. 2018 [40]	Quasi-experimental	30 Participants (EG: 15, CG: 15)	NA	EG: 16.33±0.62 CG: 16.14±0.77	Soccer	8 Weeks of core training (three times per week)	Usual soccer training (three days a week)	Pro Agility Shuttle Run test	Improved in the agility after the intervention (p≤0.05)
Sever & Zorba. 2018 [19]	Quasi-experimental	38 Participants (EG: 27 CG: 11)	NA	aged 16-20 years	Soccer	8 Weeks of static and dynamic core exercises (three 30 min sessions per week)	Usual soccer training (three days a week)	5-10-5 Shuttle test	No significant difference in agility was found (P= 0.06)
Moreira et al. 2017 [41]	Quasi-experimental	24 Participants (EG: 12, CG: 12)	24/0	EG: 15.30±0.50 CG: 15.60±.05	Soccer	9 Weeks of core exercises (three times a week)	9 Weeks of proprioceptive training (three days a week)	Square Test	Improved in the agility after the intervention (p≤0.05)

Afyon et al. 2017 [42]	Quasi-experimental	40 Participants (EG: 20, CG: 20)	NA	EG: 23.17±1.86 CG: 22.03±0.50	Soccer	8 Weeks of core exercises (four days a week, including 30 minutes tertian core training program)	Usual soccer training (four days a week)	Illinois agility test	Improved in the agility after intervention (p=0.001)
Ozmen & Aydogmus. 2016 [47]	Quasi-experimental	20 Participants (EG: 10, CG: 10)	11/9	EG: 10.90±0.30 CG: 10.80±0.40	Badminton	6 Weeks of core exercises (twice a week)	Usual badminton training (twice a week)	Illinois Agility Test	No significant difference in agility was found (p=0.160)

EG Experimental group, CG Control group, NA Not available, RCT Randomized controlled trial

Table 2: Critical appraisal results of eligible systematic reviews

Authors/ JBI Checklists for quasi-experimental studies	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Overall Score
Kahraman & Kızılca. 2025	Y	Y	Y	Y	Y	N	Y	Y	Y	8/9
Bangari et al. 2025	Y	Y	Y	Y	Y	N	Y	Y	N	7/9
Gürkan et al. 2025	Y	Y	Y	Y	Y	N	Y	Y	Y	8/9
Qureshi et al. 2025	Y	Y	Y	Y	Y	N	Y	Y	N	7/9
Amato et al. 2025	Y	Y	Y	Y	Y	N	Y	Y	Y	8/9
Sofuoğlu et al. 2024	Y	Y	Y	Y	Y	N	Y	Y	N	7/9
Shelar et al. 2024	Y	Y	Y	Y	Y	N	Y	Y	Y	8/9
Aslan & Kahraman. 2023	Y	Y	Y	Y	Y	N	Y	N	N	6/9
Merkezi et al. 2023	Y	Y	Y	Y	Y	N	Y	Y	N	7/9
Çakir & Ergin. 2023	Y	Y	Y	Y	Y	N	Y	Y	Y	8/9
Arslan & Ergin. 2022	Y	Y	Y	Y	Y	N	Y	Y	N	7/9
NabaviNik et al. 2022	Y	Y	Y	Y	Y	N	Y	N	N	6/9
Mossa. 2022	Y	Y	Y	Y	Y	N	Y	Y	N	7/9
Yılmaz. 2022	Y	Y	Y	Y	Y	N	Y	Y	N	7/9
Wondale et al. 2021	Y	Y	Y	Y	Y	N	Y	Y	Y	8/9
Özen et al. 2020	Y	Y	Y	Y	Y	N	Y	Y	N	7/9
Dinç & Ergin. 2019	Y	Y	Y	Y	Y	N	Y	Y	Y	8/9
Bashir et al. 2019	Y	Y	Y	Y	Y	N	Y	Y	N	7/9
Aslan et al. 2018	Y	Y	Y	Y	Y	N	Y	Y	N	7/9
Sever & Zorba. 2018	Y	Y	Y	Y	Y	N	Y	Y	N	7/9
Moreira et al. 2017	Y	Y	Y	Y	Y	N	Y	Y	Y	8/9
Afyon et al. 2017	Y	Y	Y	Y	Y	N	Y	Y	Y	8/9
Ozmen & Aydogmus. 2016	Y	Y	Y	Y	Y	N	Y	Y	Y	8/9

JBI Checklists for randomized controlled trials (RCT)	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Overall
Gottlieb et al. 2025	Y	Y	Y	N	N	N	Y	N	Y	Y	Y	Y	Y	10/13
Atici & Bayrakdar. 2025	Y	Y	Y	N	N	N	Y	N	Y	Y	Y	Y	Y	10/13
Kabadayı et al. 2022	Y	Y	Y	N	N	N	Y	N	Y	Y	Y	Y	Y	10/13
Arslan et al. 2021	Y	Y	Y	N	N	N	Y	N	Y	Y	Y	Y	Y	10/13