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In-Season Resistance Training Strategies for Soccer: A Systematic Review and Meta-Analysis of Isoinertial Devices Versus Conventional Methods on Change of Direction, Power, and Sprint Performance

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Abstract

Background: Flywheel training [FWT] is increasingly implemented to enhance lower-limb power in soccer players; however, its comparative effectiveness versus conventional resistance training [CRT] for soccer-specific performance outcomes remains unclear.

Objective: To systematically review and meta-analyze randomized controlled trials [RCTs] comparing FWT with CRT on countermovement jump [CMJ], sprint performance [10 m, 20 m, 30 m], and change-of-direction [COD] ability in soccer players.

Methods: PRISMA-compliant searches were conducted in PubMed, Web of Science, and Scopus up to August 14, 2025. Eligible studies were RCTs involving healthy soccer players completing ≥4 weeks of FWT or CRT and reporting at least one target outcome. Risk of bias was assessed using Cochrane RoB 2, and certainty of evidence using GRADE. Random-effects meta-analyses were performed, with heterogeneity quantified by I^2. Eight RCTs [n = 216; 196 males, 20 females; elite youth to professional levels] were included.

Results: FWT produced significantly greater improvements in CMJ performance compared with CRT [SMD = 1.73; 95% CI: 0.59–2.87; p = 0.003; I^2 = 0%]. In contrast, CRT was superior for short-distance sprint performance, with significant between-group differences favoring CRT in 10 m [MD = 0.027 s; p = 0.041; I^2 = 0%] and 20 m sprints [MD = 0.044 s; p = 0.023; I^2 = 0%]. No significant differences were observed for 30 m sprint performance (p = 0.096; I^2 = 0%] or COD ability (p = 0.275], although COD outcomes exhibited substantial heterogeneity [I^2 = 79%].

Conclusions: Both FWT and CRT effectively enhance explosive performance in soccer players. FWT preferentially improves vertical jump performance, whereas CRT yields greater benefits in short-distance sprint acceleration. Integrating both modalities within a periodized training program may provide the most comprehensive performance adaptations.

1. Introduction

Modern soccer demands repeated explosive actions, rapid accelerations (1), sudden changes of direction (2), and powerful jumps (3) requiring simultaneous development of neuromuscular power (4) and sport-specific muscular adaptations (5, 6). Flywheel training (FWT) delivers maximal eccentric overload (7) across the full range of motion, induces substantial stimulation of muscle spindles (8) and tendon stretch receptors (9), enhancing stretch reflex sensitivity and optimizing force production within the stretch–shortening cycle (SSC) (10). This mechanism not only improves neural drive and increases the rate of force development but also aligns closely with the biomechanical demands of high-velocity soccer movements (11). Furthermore, integrating FWT into diverse training paradigms including linear and undulating periodization models, speed–power complexes, and multidirectional plyometrics, enables simultaneous recruitment of fast-twitch fibers (12), improvement of motor unit firing efficiency (13), and promotion of both metabolic and structural adaptations (14).

The exercise science advantage of FWT arises from its capability to match and exceed concentric effort with proportionally greater eccentric loading (15), a condition that traditional constant-load resistance systems cannot produce (16). Flywheel devices work by using inertial resistance from the cable as it unwinds and rewinds (17). In the concentric phase, the athlete pulls the cable, making the flywheel spin and create resistance

(18). When the cable rewinds, the muscles work in the eccentric phase. The harder the athlete pulls in the concentric phase, the greater the resistance in the eccentric phase (19). In soccer, this ability to overload the eccentric phase is critical for improving braking capacity (20), deceleration control (10), and force absorption during directional changes qualities strongly correlated with injury prevention and enhanced COD efficiency (21). Additionally, the heightened activation of type IIx fibers under high eccentric load supports superior adaptations in maximal strength and power output, facilitating faster sprint acceleration over short distances (22, 23).

From a neurophysiological perspective, FWT exploits the sensitivity of muscle spindles during rapid lengthening (24), enhancing proprioceptive feedback and reflex-based contraction potentiation (25). Such adaptations improve intra-muscular coordination and can shift the force–velocity profile toward more advantageous sprint and jump outputs (26). The acute stretch-reflex potentiation seen after FWT sessions may also contribute to post-activation performance enhancement (PAPE), creating practical windows for pairing FWT with technical–tactical drills in a training micro cycle (27, 28).

In terms of periodization, FWT's mechanical and neural specificity allows it to be placed strategically across the season (29, 30). In early preparatory phases, it can drive hypertrophy of type II fibers and develop baseline strength, while in competitive phases, it supports maintenance of peak force and power without the excessive central fatigue often associated with high-volume traditional lifting (31). Moreover, FWT's adaptability whether applied bilaterally or unilaterally, in sagittal or frontal plane movements, supports the principle of dynamic correspondence by mirroring the multidirectional force demands of match play (32).

While evidence supports FWT's effectiveness for improving CMJ and short sprints, its comparative benefits versus CRT for various soccer-specific performance outcomes remain unclear. Meta-analytical synthesis of randomized controlled trials can help clarify whether performance gains are exercise-specific, neuromuscular generalizable, or preferentially expressed in certain movement patterns. Understanding these differential effects can guide strength and conditioning coaches in selecting the optimal integration of FWT and CRT for specific positional or seasonal goals.

2. Results

2.1 Study selection

The study selection process followed the PRISMA guidelines and is illustrated in Fig. 1. *Initially, a total of 276 records were identified through systematic database searches across PubMed (224 records), Web of Science (23 records), and Scopus (29 records). After the removal of 29 duplicate records and 219 records marked as ineligible by automation tools, 29 records remained for further screening. In the screening phase, the titles and abstracts of the 29 records were reviewed to identify potentially relevant studies. During this process, 9 records were excluded: 4 review articles* (33–36) *and 5 articles that focused on rehabilitation topics* (37–40). *This left 20 reports for full-text eligibility assessment. To ensure comprehensive coverage, 2 additional studies were identified through searches of other relevant data sources (e.g., Google Scholar). In the eligibility phase, the full texts of the 22 reports were carefully reviewed, leading to the exclusion of 9 reports for the following reasons: inclusion of non-athlete participants (n = 6)* (13, 41–45), *lack of focus on performance (n = 1)* (46), *and absence of a comparison group (n = 2)* (47, 48), *where studies implemented only one protocol [flywheel or traditional training]. After completing the systematic selection process, a total of 13 studies met the predefined inclusion*

criteria and were initially included in the meta-analysis. However, since the present study aimed to specifically compare interventions in the context of soccer, five of these studies conducted in other team sports such as basketball, rugby, Handball were excluded from the final synthesis(49–53). *Ultimately, eight studies specifically involving soccer players were included in the final meta-analysis, ensuring sport-specific relevance and comparability. This rigorous, multi-step screening ensured that only high-quality, directly comparable studies in the target sport were analyzed.*

2.2 Descriptive Characteristics of the Studies

The eight studies included in the final meta-analysis comprised a total of 216 soccer players, of which 196 were male and 20 were female. The male participants ranged from elite youth (U16) to professional and semi-professional levels, while the female participants were all professional players competing in a first-division league. By competition level, the sample included: Elite youth players: 20 male U16 players (29) *and 18 junior elite players* (30). *Elite senior players: 28 male professionals* (10) *and 18 male first-division professionals* (21). *Semi-professional players: 40 males from Italian Serie D* (54) *and 34 semi-professionals* (55). *Professional female players: 20 from Spain's First National Division* (56). *Recreational-level adult male players: 38* (20).

Positional data were explicitly reported only in studies by Pecci et al. (2023) (56): *goalkeepers [n = 3], central backs (n = 5), full backs [n = 4], central midfielders (n = 5), lateral midfielders [n = 4], and forwards (n = 3), and by Coratella et al. (2019)* (54), *where participants represented a balanced distribution across defensive, midfield, and forward positions in two semi-professional squads. The other studies involved whole-team samples without positional breakdowns. The age range across studies spanned from 15.5 ± 0.4 years in elite youth players to 24.1 ± 1.8 years in senior professionals, with a mean pooled age across all samples of approximately 21.4 years. League levels varied from top-tier national competitions (professional male and female squads] to lower-division clubs (Italian Serie D), as well as youth elite academies and recreational adult squads. Intervention characteristics ranged from 6 to 10 weeks in duration, with frequencies of 1–2 sessions per week, often integrated into in-season schedules, except for Sagelv et al. (2020)*(57), *where the program was implemented during the pre-season. A summary of participant demographics, competition level, and key performance measures for each study is provided in* Table 1.

Table 1
Demographic variable of Included papers.

Study [Year]	Sample & Age	League / Positions	Duration / Frequency	Flywheel training program	Control group training	Outcome
Coratella et al. 2019 (54)	40 M semi-pro, 23 ± 4 y	Italian Serie D, mixed positions	8 wks / 1×wk	Squat on flywheel [inertia 0.11 kg·m²], 4×12 reps, 48 reps' total/session	Traditional weight training – back squat at 80% 1RM, same volume as flywheel group	COD ↑, Jump ↑ [CMJ], Sprint ↑ [10 m, 30 m]
de Hoyo et al. 2015 (58)	18 M junior elite, 17.1 ± 0.5 y	Elite U19	10 wks / 2×wk	Half-squat on flywheel, progressive overload, 3–4 sets	Traditional weight training – half squat with barbell at progressive loads	Jump ↑ [CMJ], Sprint ↑ [10 m, 20 m]
Edvars et al. 2020(20)	38 M recreational, 22.3 ± 3.1 y	Amateur league	6 wks / 2×wk	Flywheel squat, maximal intent velocity, 3×6–8 reps	High-load free-weight squats [≥ 85% 1RM], maximal intent velocity	Jump ↑ [CMJ], Sprint ↑ [10 m]
Raya-González et al. 2021(59)	20 M U16 elite, 15.5 ± 0.4 y	Elite academy	10 wks / 1×wk	Lateral squat on flywheel [0.025–0.050 kg·m²], 3–4 sets × 6 reps	Traditional strength training – bilateral half squat with free weights	Jump [CMJ] ↑, Sprint [10 m, 20 m, 30 m] ↑
Nuñez et al. 2019(55)	34 M semi-pro, 22.6 ± 2.5 y	Regional semi-pro	6 wks / 2×wk	Flywheel squat, step-up, Romanian deadlift, 3×8 reps, moderate-high inertia	Traditional resistance training – squat, step-up, Romanian deadlift with free weights	Jump ↑, Sprint ↑
Jakub Jarosz et al. 2023(60)	28 M elite, 23.2 ± 2.9 y	Top division	4 wks / 2×wk	Flywheel squat + forward or lateral split squat, 3×8 reps	Traditional free-weight training – back squat + split squats	COD ↑, Jump ↑, Sprint ↑
Pecci et al. 2023(56)	20 F prof., 20.4 ± 2.6 y	Spain First Division;	6 wks / 2×wk	Flywheel squat [0.025 kg·m²], start 3×6 reps, progressive ↑ volume & intensity	Traditional soccer strength training – no flywheel; standard S&C drills on field + gym	COD →, Jump →, Sprint → [10 m, 30 m]
Fajardo et al. 2016(21)	18 M professional, 24.1 ± 1.8 y	First division	6 wks / 2×wk	Flywheel leg-curl & lunge, 3×6–8 reps	Traditional resistance training – half-squat with	COD ↑ [10 m], JumpNR, Sprint ↑

Legend: *↑ = Improved; → = No significant change; ↓ = Decreased; NR = Not reported, COD = Change of direction*

Study [Year]	Sample & Age	League / Positions	Duration / Frequency	Flywheel training program	Control group training	Outcome
					barbell at matched volume	

Legend: *↑ = Improved; → = No significant change; ↓ = Decreased; NR = Not reported, COD = Change of direction*

2.3 Risk of Bias in Included Studies

*The methodological quality of included trials was assessed using the Cochrane Risk of Bias 2 [RoB 2] tool, adapted for exercise-based sport science interventions. All studies showed low risk in the randomization process, minimizing selection bias. As participant and personnel blinding was unfeasible in soccer-specific training, all trials had moderate to high performance bias. Outcome assessor blinding varied, yielding moderate detection bias in some cases. Attrition and reporting biases were generally low, with minimal loss to follow-up and no evidence of selective reporting. Overall, most trials were rated as having a moderate risk of bias, largely due to unavoidable blinding limitations in field-based performance research (*Table 1s*).*

2.4 Bias in Publication and Sensitivity Analysis

As showed in Table 2, *According to Begg's rank correlation test, no significant publication bias was detected for any of the analyzed outcomes. The p-values were as follows: 10-m sprint (p = 0.259], 20-m sprint (p = 0.308), CMJ (p = 0.071), COD (p = 0.734), and 30-m sprint (p = 0.734). Similarly, based on Egger's regression test, there was no evidence of publication bias for the included studies. The p-values were: 10-m sprint (p = 0.196], CMJ (p = 0.339], COD (p = 0.374), and 30-m sprint (p = 0.842), However, a significant publication bias was detected for the 20-m sprint (p = 0.034). The funnel plots are presented in* Fig. 1S, *providing a graphical representation of the relationship between study size and observed effect sizes, comparing pre- and post-intervention results. Using the trim and fill method, 3, 4, 7, 0, and 4 potentially missing studies were estimated for the 10-m sprint, 20-m sprint, CMJ, 30-m sprint, and COD, respectively, and were subsequently imputed into the meta-analysis. Publication bias was further assessed by evaluating the symmetry of the funnel plots. All plots are available in the Supplementary File (*Fig. 1s *Panel A-E).*

Table 2
Assessment of publication bias in the comparison of fly wheel training vs traditional training in soccer.

	Corrected effect size		Beg's rank correlation test			Eager's linear regression test					Fail safe N test
	WMD	95% CI	Kendall's tau	z-value	P-value	Intercept	95% CI	t	df	P-value	n
10-M	-0.023	-0.049 – 0.001	-4.000	1.127	0.259	-1.676	-4.685 – 1.332	1.546	4	0.196	3
20-M	-0.035	-0.069 — -0.001	-5.000	1.019	0.308	-1.999	-3.651 - -0.346	5.205	2	0.034	4
CMJ	1.725	0.586 - 2.864	-0.571	1.802	0.071	-1.670	-5.734 -- 2.393	1.056	5	0.339	7
30-M	-0.284	-0.679 -- 0.110	1.166	0.339	0.734	1.020	-18.497 -- 20.537	0.833	2	0.842	0
COD	-0.233	-0.582 - 0.114	-0.166	0.339	0.734	-2.922	-14.009 -- 8.165	1.133	2	0.374	4

2.5 Certainty of Evidence [GRADE Assessment]

The certainty of evidence for primary outcomes (CM) height, 10 m, 20 m, 30 m sprint times, and COD performance] was evaluated using the GRADE approach. All evidence was derived from RCTs with soccer players, eliminating concerns over indirectness; no publication bias was detected. CMJ and 10 m sprint had moderate certainty, downgraded for some risk of bias [incomplete blinding, allocation concealment issues] and imprecision due to modest sample sizes. The 20 m sprint showed low-to-moderate certainty, downgraded for imprecision from few studies and marginal significance. The 30 m sprint had low certainty due to small samples, wide confidence intervals, and inconsistency. COD performance also had low certainty, driven by substantial heterogeneity in protocols, tests, and player characteristics, plus limited sample size. Details are summarized in Table 2s.

2.6 Primary Analysis

2.6.1 Muscle Power Analysis Result [Countermovement Jump]

For muscle power, measured by CMJ, a significant improvement was found with FWT compared to CRT. The standardized mean difference (SMD) was 1.726 [95% CI: [0.587, 2.865], p = 0.003], indicating a notable enhancement in muscle power following FWT, as displayed in Fig. 2. *The heterogeneity was negligible [Tau² ≤ 0.0001, Chi² = 5.045, df = 6, p = 0.538, I² = 0.00%], supporting the consistency of this result across the included studies.*

2.6.2 Speed Analysis Result [10-m Sprint]

A statistically significant improvement in 10-meter sprint performance was observed in favor of \ CRT compared to FWT. The standardized mean difference (SMD) was − 0.027 [95% CI: [-0.053, -0.001], p = 0.041], as illustrated in Fig. 3. *Heterogeneity was absent [Tau² ≤ 0.0001, Chi² = 3.992, df = 5, p = 0.551, I² = 0.00%], indicating consistency of this result across the included studies.*

2.6.3 Speed Analysis Result [20-m Sprint]

A statistically significant improvement in 20-meter sprint performance was observed in favor of CRT compared to FWT. The standardized mean difference (SMD) was − 0.044 [95% CI: [-0.081, -0.006], p = 0.023], as illustrated in Fig. 4. *Heterogeneity was absent [Tau² ≤ 0.0001, Chi² = 2.253, df = 3, p = 0.522, I² = 0.00%], indicating that the effect was consistent across the included studies.*

2.6.4 Speed Analysis Result [30-m Sprint]

No statistically significant difference in 30-meter sprint performance was observed between FWT and CRT. The SMD was − 0.092 [95% CI: [-0.201, 0.016], p = 0.096], as illustrated in Fig. 5. *Heterogeneity was absent [Tau² ≤ 0.0001, Chi² = 2.953, df = 3, p = 0.399, I² = 0.00%], indicating consistent results across the included studies.*

2.6.5 Change of direction Analysis Result [COD]

No statistically significant difference in COD performance was observed between FWT and CRT. standardized mean difference (SMD) was − 0.234 [95% CI: [-0.582, 0.115], p = 0.275], as illustrated in Fig. 6. *The analysis revealed substantial heterogeneity [Tau² = 2.024, Chi² = 14.482, df = 3, p = 0.002, I² = 79.28%], indicating considerable variability in results across the included studies.*

2.7 Sensitivity Analysis

*Leave-one-out sensitivity analyses indicated that primary outcome findings (1RM, CMJ, 10 m, 20 m, 30 m sprint, COD) were generally robust. Notable changes in statistical significance occurred for 20 m sprint (excluding Raya González et al.), and COD (excluding Pecci et al.). all other outcomes remained stable. (*Fig. 2s, *panels A–E).*

3. Discussion

The results of this meta-analysis indicate distinct, outcome-specific effects of in-season resistance training modalities in soccer players. FWT produced large and statistically significant improvements in CMJ performance, highlighting its ability to improve vertical power by using eccentric overload and making the stretch shortening cycle more efficient. No significant differences were found between the groups for 30 m sprint or COD performance. However, the wide variation in COD results suggests that study methods and participant

characteristics may have influenced the outcomes. To fully understand these findings, it is essential to consider not only the physiological mechanisms underlying each training modality but also the contextual factors that may have shaped the observed effects. One of the main challenges in interpreting the current evidence is the variability among included studies in terms of exercise selection, loading parameters, training frequency and duration, and integration with sport-specific drills. This diversity likely influenced performance outcomes and contributed to the heterogeneity observed particularly for COD making direct comparisons between studies more complex.

Muscle Power [CMJ]

The present meta-analysis demonstrated a large and statistically significant effect of FWT on CMJ performance compared with CRT [SMD = 1.726; 95% CI: 0.587 to 2.865; p = 0.003], with negligible heterogeneity (I^2 = 0%), indicating high consistency across trials. This finding reinforces the notion that the eccentric-overload stimulus inherent to FWT elicits substantial improvements in lower-limb muscle power, particularly within the stretch–shortening cycle (14). The capacity of FWT to generate high eccentric forces at individualized maximal levels, independent of gravitational loading, likely promotes adaptations in type II muscle fibers, enhances rate of force development, and improves neuromuscular efficiency key determinants of vertical jump performance in soccer (30). Previous studies have similarly reported superior CMJ gains from FWT compared to traditional free weights, attributing this to greater eccentric loading, increased muscle–tendon stiffness, and more pronounced post-activation potentiation effects (32). From a practical perspective, these adaptations may translate into more explosive actions such as aerial duels, heading, and first-step speed, all of which are critical in match performance (54). Given the low between-study variability in our analysis, the superiority of FWT for CMJ appears robust across different player populations and training contexts.

Speed 10-M:

The meta-analysis identified a small but statistically significant advantage of CRT over FWT for 10 m sprint performance [SMD = 0.027; 95% CI: 0.053 to 0.001; p = 0.041], with no observed heterogeneity (I^2 = 0%), indicating high consistency of this effect across the included trials. while FWT provides substantial eccentric overload, its specificity may be more favorable for vertical force-oriented task (12), with potentially less transfer to horizontal acceleration mechanics without complementary sprint-specific work. These findings align with previous research in elite and sub-elite soccer players showing that heavy resistance and Olympic-style lifting interventions can significantly reduce sprint times over distances ≤ 20 m (61). From an applied perspective, this suggests that when acceleration development is a primary objective during the competitive period, CRT may offer superior benefits for the first 10 m of sprinting, while FWT could be integrated for its vertical power enhancements and injury-mitigation potential.

Speed 20-M:

The meta-analysis revealed a small but statistically significant advantage of CRT over FWT in 20 m sprint performance [SMD = 0.044; 95% CI: 0.081 to 0.006; p = 0.023], with no heterogeneity detected (I^2 = 0%), indicating consistent findings across studies. The continued superiority of CRT from 10 m to 20 m suggests that its benefits extend beyond initial acceleration into the transition phase, where athletes shift from force-dominant to velocity-dominant running mechanics (2). Heavy-load CRT likely increases maximal force production capacity and enhances the ability to apply high propulsive forces over a longer duration of the sprint start, thereby

improving both initial acceleration and the build-up to maximal sprint velocity (61). While FWT effectively improves eccentric strength and vertical power, the transfer to horizontal sprint velocity may be limited without targeted sprint-specific or resisted-run training modalities (16). Similar results have been reported in soccer and rugby athletes, where high-load free-weight and Olympic-lifting interventions reduced sprint times over 20 m and improved both stride length and rate (51). From a practical perspective, CRT appears more effective for mid-distance acceleration, a key performance component in soccer for closing down opponents, transitioning between phases of play, and creating separation during attacking runs.

Speed 30-M:

The meta-analysis found no statistically significant difference between FWT and CRT for 30 m sprint performance [SMD = -0.092; 95% CI: 0.201 to 0.016; p = 0.096], with no heterogeneity observed (I^2 = 0%). This lack of difference suggests that over longer sprint distances where maximal velocity mechanics predominate the distinct training stimuli provided by CRT and FWT may yield comparable adaptations in velocity-oriented phases (58). Both modalities can enhance neuromuscular function, lower-limb power output, and stretch-shortening cycle efficiency, which are critical for maintaining high sprint speeds beyond the initial acceleration phase (33). In the context of soccer, maximal velocity is less frequently reached in match play compared to short accelerations, which may reduce the sport-specific advantage of one modality over the other for this distance. Previous studies on mixed-sport populations have similarly reported equivalent improvements in flying sprints or peak velocity following either high-load resistance or eccentric overload interventions, provided that sprint-specific drills were incorporated alongside strength training (16, 47). Practically, this indicates that both CRT and FWT can be viable for supporting top-end sprint performance if combined with high-velocity sprinting practice, plyometrics, and resisted sprints in periodized training plans.

Change of Direction – COD:

The meta-analysis detected no statistically significant difference between FWT and CRT for COD performance [SMD = 0.234; 95% CI: 0.582 to 0.115; p = 0.275]. However, the analysis revealed substantial heterogeneity (I^2 = 79.28%), indicating considerable variability among study results. Such heterogeneity may stem from differences in COD testing protocols (e.g., 505, T-test, Illinois), training durations, participant profiles (elite vs. amateur), and the extent to which the interventions integrated sport-specific COD drills alongside resistance training. COD performance is a multifactorial skill involving not only concentric and eccentric lower-limb strength but also technique, deceleration control, and re-acceleration capability (56). While FWT provides pronounced eccentric overload that may enhance braking capacity, CRT can facilitate higher concentric force outputs that benefit re-acceleration. The absence of a clear advantage for either modality suggests that improvements in COD likely depend on combining strength-oriented interventions with specific agility and reactive change-of-direction drills (54). This aligns with previous literature indicating that strength gains alone, regardless of modality, do not fully transfer to COD performance without task-specific movement practice (59). Coaches may consider periodized approaches that integrate both heavy-resistance or eccentric overload training with COD-specific field drills to maximize performance benefits.

Study limitations

This meta-analysis presents several important limitations that should be considered when interpreting the results. First, substantial heterogeneity was observed for certain outcomes, particularly COD performance [I^2 =

79%], suggesting notable variability between studies in COD testing protocols, training volume, equipment parameters, participant characteristics, and whether interventions were paired with sport-specific drills. Although heterogeneity for sprint and CMJ outcomes was low [I^2 = 0%], the small number of studies per outcome limited the statistical power to detect potential moderators. Second, the number of high-quality randomized controlled trials directly comparing FWT and CRT in soccer is limited, and sample sizes were generally small, which may have increased model sensitivity to the influence of individual studies. This constraint also precluded the use of robust meta-regression to fully explore the effects of moderators such as training duration, frequency, and inertial load. Third, the generalizability of findings is limited by the predominance of male participants, with minimal inclusion of female athletes and youth populations. Fourth, methodological challenges such as the impossibility of blinding in exercise-based interventions, differences in load prescription [e.g., %1RM vs. inertial moment of force], and variability in measurement technologies (e.g., force platforms, optical timing gates, or field-based tests) may have introduced additional bias. Restricting included studies to publications in English also raises the possibility of publication and language bias.

Finally, the majority of studies assessed short-term training interventions (≤ 10 weeks), leaving uncertainty about the sustainability of observed improvements over a full competitive season or multiple seasons. Future research should prioritize larger, well-powered RCTs with standardized protocols, greater inclusion of female and youth players, and long-term follow-up assessments. Additionally, studies systematically evaluating combination training strategies (integrating FWT, CRT, plyometrics, and sprint/COD-specific drills) are needed to identify the most effective programming models for optimizing soccer performance.

4. Materials and Methods

4.1 Protocol and Registration

This meta-analysis was conducted following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure methodological transparency and rigor [62]. The study protocol was pre-registered in the International Prospective Register of Systematic Reviews (PROSPERO 2025 CRD420251126436. Available from: https://www.crd.york.ac.uk/PROSPERO/view/CRD420251126436.

4.2 Search Strategy

A systematic search of PubMed, Web of Science, and Scopus was performed to identify studies comparing FWT and Conventional Resistance Training (CRT) in soccer players. The search was performed until August 14, 2025, and aimed to find papers that examined the effects of FWT versus CRT specifically in soccer players. The search terms used included: ((“soccer” OR “soccer players” OR “football players” OR “Football”) AND (“Isoinertial flywheel training” OR “flywheel resistance training” OR “flywheel training” OR “inertial training” OR “isoinertial exercise” OR “eccentric”) AND (“traditional resistance training” OR “weight training” OR “strength training” OR “conventional resistance training”) AND (“athletic performance” OR “muscle strength” OR “muscle power” OR “explosive strength” OR “jump height” OR “speed” OR “sprint performance” OR “10-meter sprint” OR “20-meter sprint” OR “agility” OR “change of direction”)). Filters were applied when necessary to refine the search to only include studies published in English and studies that reported the desired outcomes. A manual review of the reference lists of relevant studies was also conducted to identify any additional articles not captured in the electronic search.

This search strategy ensured the identification of studies relevant to the research question, with a focus on those that compared the effects of FWT and CRT on soccer performance outcomes, including strength, power, speed, and agility.

4.3 Inclusion/Exclusion Criteria

To evaluate the eligibility of studies, a Participants, Intervention, Comparators, Outcomes, and Study Design (PICOS) approach was applied. Articles were eligible for inclusion if they met the following criteria: the study was a randomized controlled trial (RCT); participants were healthy soccer players, with no restrictions on gender, competition level, or playing position; the study included a FWT intervention alongside a control or alternative intervention group to evaluate adaptations in strength and/or power; the FWT protocol lasted at least four weeks; and the study reported at least one soccer-related performance outcome, including power (e.g., countermovement jump height, peak power), speed (e.g., 10-meter), or change of direction (e.g., T-test or similar performance tests).

Studies were excluded if they were not randomized controlled trials, did not meet the minimum training protocol requirements (e.g., duration or frequency), were literature reviews, abstracts, editorials, commentaries, or letters to the editor, were not written in English, did not report means and standard deviations with no response from the authors upon inquiry, or if participants had any pathology or were undergoing treatment for musculoskeletal injuries in the trained limb. The titles and abstracts obtained from the search were imported into EndNote 21, where duplicates were removed and cross-references were verified. Two independent reviewers evaluated all potentially relevant studies and retrieved the full-text articles when necessary.

4.4 Study Selection and Data Extraction

Two reviewers (S.A and K.R) independently collected key data on participants, interventions, and outcomes using a standardized extraction form, focusing exclusively on studies involving soccer players. Missing details were obtained by contacting study authors or, when necessary, extracted from figures using Web Plot Digitizer V4.7. All extracted data were checked by a second reviewer for accuracy. The main variables included participant information (age, body mass, height, sex, playing position, competitive level, and total sample size), intervention details (type of exercises, session frequency, total training duration, number of sets and repetitions, and training intensity), and performance outcomes comprising sprint times over 10 m, 20 m, and 30 m, COD performance measured through tests such as the T-Test or similar protocols, and muscle power assessed by CMJ height. Reviewers' agreement was quantified using the intraclass correlation coefficient (ICC), yielding excellent reliability (ICC = 0.90). Discrepancies were resolved by consensus before statistical analysis. A random-effects model was applied for meta-analysis, and between-study heterogeneity was evaluated using the I^2 statistic. This methodology ensured data accuracy, completeness, and impartiality for the systematic review [63].

4.5 Quality Assessment and Risk of Bias and Certainty of Evidence Assessment

The Cochrane Risk of Bias 2 (RoB2) tool [64] was applied to assess the internal validity of the papers, examining potential biases such as selection bias, performance bias, detection bias, attrition bias, reporting bias, and other relevant biases. Two independent authors (MM.E and S.A) evaluated the studies, and also resolving differences by the corresponding author. All Eight studies included in the quantitative analysis were longitudinal, and the final determinations ensured a thorough and careful evaluation of potential biases. In addition, the certainty of the

cumulative evidence for each primary outcome (CMJ, 10 m, 20 m, 30 m sprint times, COD performance) was graded according to the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach [65]. This involved consideration of risk of bias, inconsistency, indirectness, imprecision, and publication bias. Certainty ratings were categorized as high, moderate, low, or very low based on predefined criteria, with downgrading applied where methodological limitations, inconsistency of results, small sample sizes, or other concerns were present.

4.6 Statistical Methods and Data Analysis

The statistical analyses for this systematic review and meta-analysis were conducted using Comprehensive Meta-Analysis (CMA) software, version 3. This software was used to perform a variety of tasks, including combining data, conducting subgroup analyses, generating forest plots, evaluating heterogeneity, and checking for publication bias. For the primary outcomes power, speed (10m and 20m sprints), and agility, standardized mean differences (SMD) along with their corresponding 95% confidence intervals (CIs) were calculated. This method was appropriate due to the continuous nature of the data. The effect sizes were categorized as small (SMD = 0.2), medium (SMD = 0.5), and large (SMD ≥ 0.8), based on Cohen's guidelines [66]. The I^2 statistic was used to assess heterogeneity, determining the extent of variability between studies as opposed to random chance. The chi-squared test and I^2 values of 25%, 50%, and 75% indicated low, moderate, and high heterogeneity, respectively, with a p-value of less than 0.05 indicating significant heterogeneity [67]. A fixed-effects model was applied when heterogeneity was not significant, while a random-effects model was used for studies with significant variability. Subgroup and sensitivity analyses were performed to examine potential moderators and assess result stability [68]. Forest plots were generated to visualize effect sizes, and funnel plots were used to check for publication bias. These statistical methods ensured a robust and thorough analysis, supporting the conclusions of the systematic review.

5. Conclusions

In conclusion, the findings of this meta-analysis indicate clear performance-specific effects of in-season isoinertial FWT and CRT in soccer players. FWT demonstrated a substantially greater impact on muscle power, as evidenced by large and significant improvements in CMJ performance, highlighting its efficacy for enhancing eccentric strength, stretch–shortening cycle function, and neuromuscular efficiency. In contrast, CRT yielded superior outcomes in short- and mid-distance sprint performance (10 m and 20), likely reflecting its benefits for maximal force production, horizontal force application, and rate of force development during acceleration phases. No statistically significant differences were observed for 30 m sprint or COD performance, although considerable heterogeneity in COD outcomes suggests that task-specific training integration is essential for maximizing agility transfer. From a practical standpoint, these results suggest that periodized programming that strategically combines FWT [to enhance vertical power and eccentric braking capacity] with CRT [to improve horizontal force production and sprint acceleration] may provide the most comprehensive performance benefits for soccer athletes. Given the multi-directional and high-intensity intermittent nature of the sport, integrating modality-specific strengths into a unified training plan could address diverse physical demands more effectively than a single-modality approach. Future research should examine the effectiveness of such combined or hybrid interventions, incorporating complementary elements such as plyometrics, resisted sprints, and COD-specific drills to optimize performance gains and sport-specific transfer.

Abbreviations

The following abbreviations are used in this manuscript:

CMJ	Countermovement Jump
COD	Change of Direction
CRT	Conventional Resistance Training
FWT	Flywheel Training
GRADE	Grading of Recommendations Assessment, Development and Evaluation
ICC	Intraclass Correlation Coefficient
MD	Mean Difference
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RCT	Randomized Controlled Trial
RoB 2	Risk of Bias Tool, Version 2 (Cochrane)
SMD	Standardized Mean Difference
SSC	Stretch–Shortening Cycle
CI	Confidence Interval
CMA	Comprehensive Meta-Analysis
U16 / U19	Under 16 / Under 19 Years of Age

Declarations

6. Patents

The authors declare that there are no patents resulting from the work reported in this manuscript.

Author Contributions: Conceptualization, **M.M.E.-K.** and **F.M.C.**; methodology, **M.M.E.-K.**, **S.A.-S.**, and **K.R.**; software, **M.M.E.-K.**; validation, **F.M.C.**, **P.N.**, and **H.N.**; formal analysis, **M.M.E.-K.** and **A.S.**; investigation, **M.M.E.-K.**, **S.A.-S.**, and **K.R.**; resources, **R.S.-G.** and **A.T.**; data curation, **M.M.E.-K.** and **K.R.**; writing—original draft preparation, **M.M.E.-K.**; writing—review and editing, **F.M.C.**, **P.T.N.**, **A.S.**, and **H.N.**; visualization, **M.M.E.-K.**; supervision, **F.M.C.** and **P.N.**; project administration, **M.M.E.-K.**; funding acquisition, **Not applicable**. All authors have read and agreed to the published version of the manuscript.

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This study is a systematic review and meta-analysis based exclusively on data from previously published studies and did not involve any new experiments with human participants or animals.

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Data Availability Statement: All data supporting the findings of this study are included within the article and its Supplementary Materials. No new datasets were generated, and no external data repository was used. Extracted datasets and statistical analysis files are available in the Supplementary Materials and from the corresponding author upon reasonable request.

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Figures

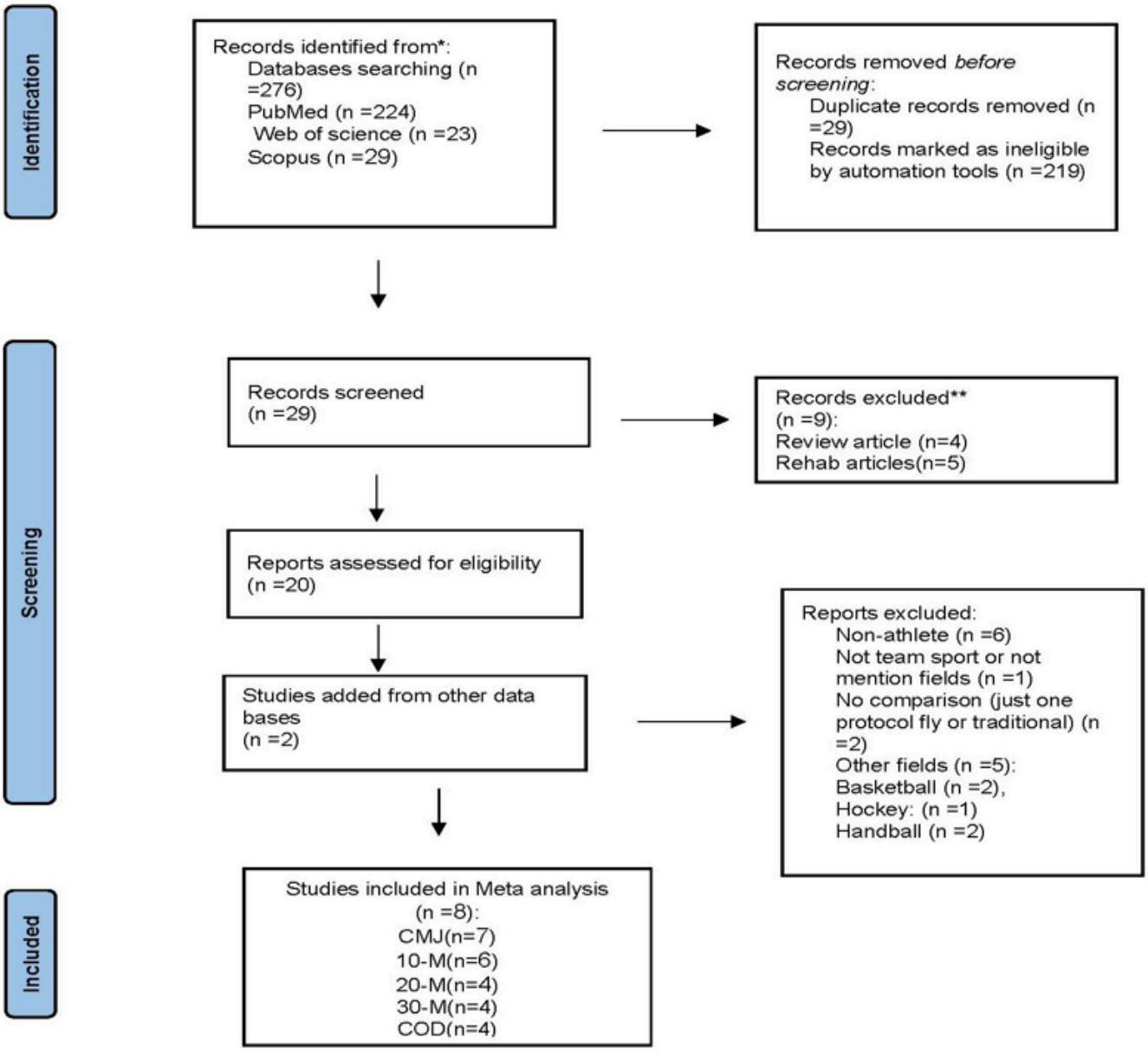


Figure 1

flow chart of PRISMA to include and exclude papers.

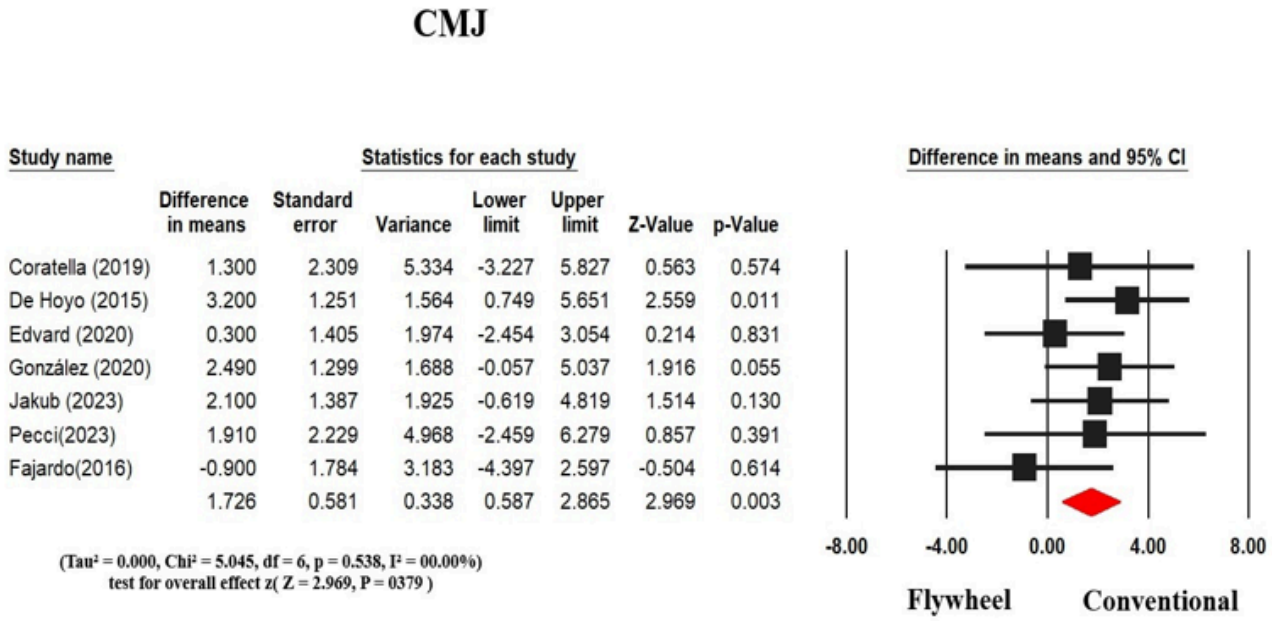


Figure 2

Forest plot with meta-analysis of standardized mean difference showing the comparison of CMJ test.

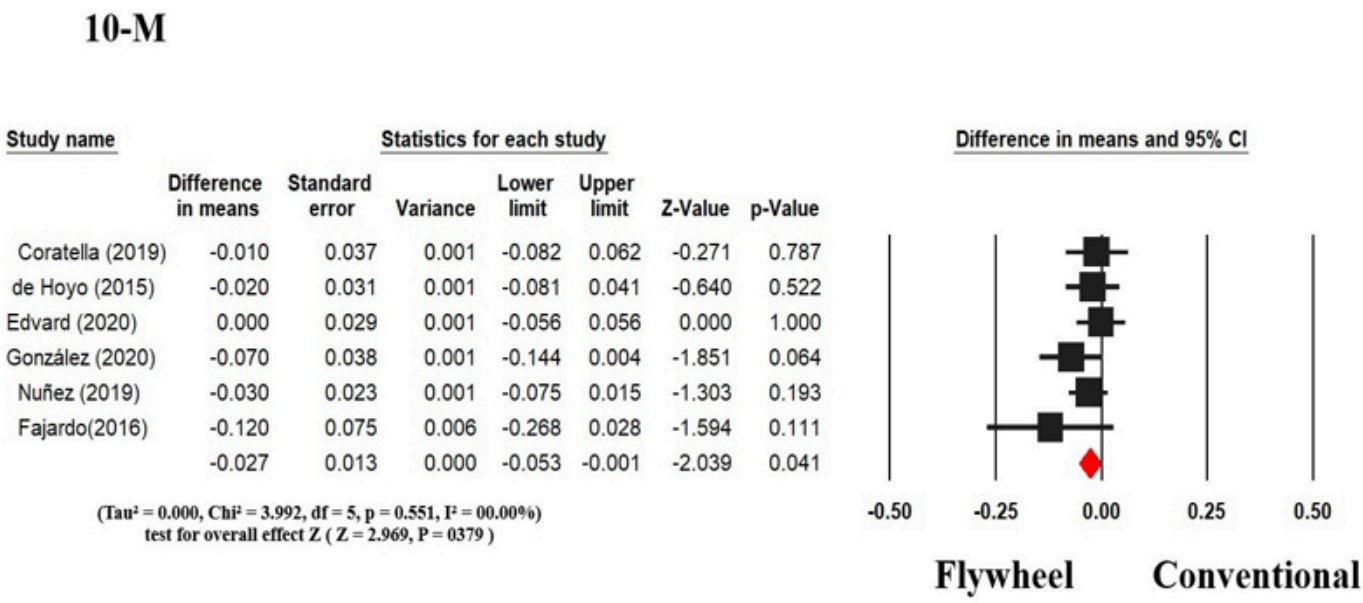


Figure 3

Forest plot with meta-analysis of standardized mean difference showing the comparison of 10-M test.

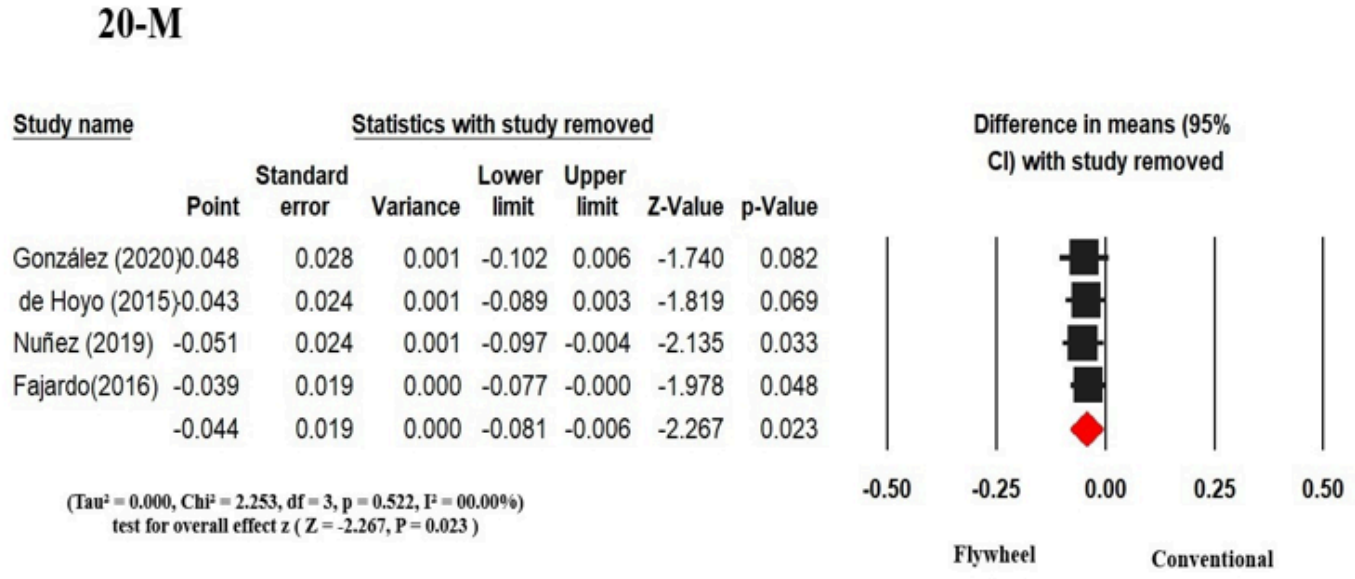


Figure 4

Forest plot with meta-analysis of standardized mean difference showing the comparison of 20-M test.

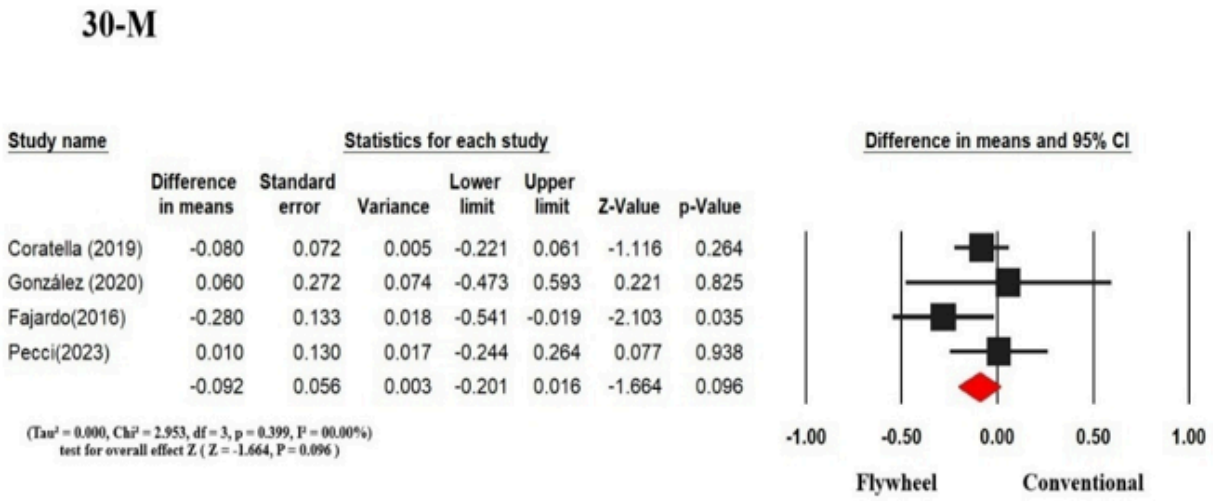


Figure 5

Forest plot with meta-analysis of standardized mean difference showing the comparison of 30-M test.

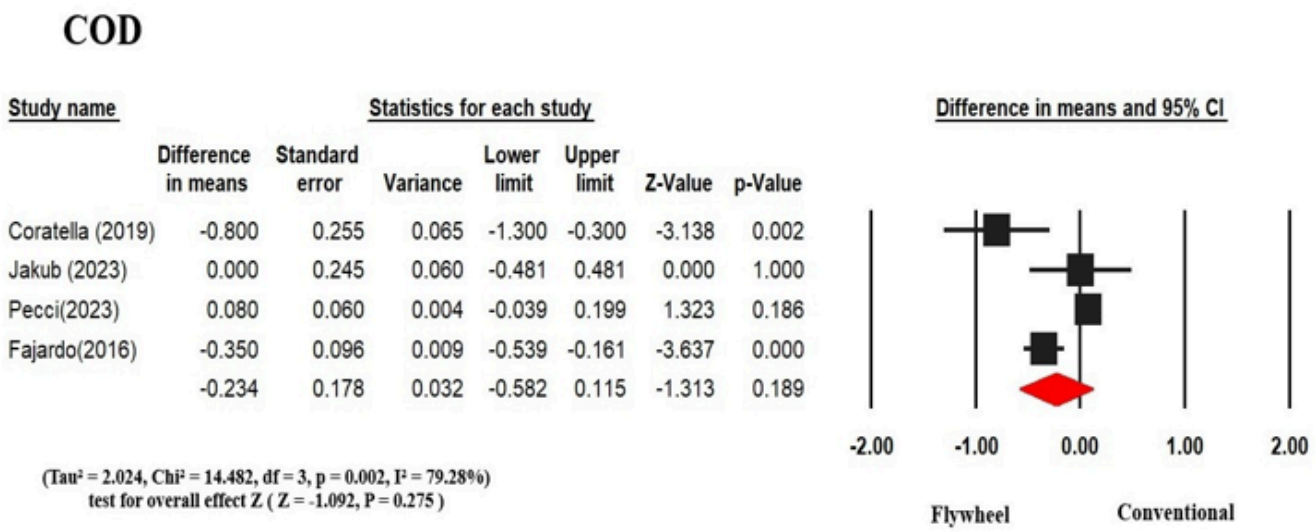


Figure 6

Forest plot with meta-analysis of standardized mean difference showing the comparison of Change of direction test.

Supplementary Files

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- Supplementary.docx