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Section III – Sports and Physical Activity

Intervention Effects of Cluster Training on Sports Performance in Athletes: A Systematic Review and Meta-Analysis

by

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Previous research has demonstrated the effects of cluster training on muscle hypertrophy, strength, and muscular endurance compared with traditional resistance training (RT), but its effects on other sport performance-related outcomes, particularly in athletes, have not been fully explored. This study aimed to perform a meta-analysis of the intervention effects of cluster training on sports performance in athletes. The CNKI, Google, PubMed, Web of Science, Cochrane Library, and EMBASE databases were searched for randomised controlled trials on the effects of cluster training on sports performance in athletes. R software, version 4.2.0 was used to draw forest plots, calculate pooled effect sizes, and perform subgroup analyses. Fifteen studies, involving 317 participants and with a mean quality score of 7.3, were included. Cluster training significantly improved short-distance sprint performance (20-m and 30-m) in athletes compared to RT (SMD = −0.44, 95% CI [−0.88, 0.00], $p < 0.05$). However, in terms of agility (SMD = −0.82, 95% CI [−2.29, 0.65], $p = 0.24$), strength (SMD = 0, 95% CI [−0.23, 0.22], $p = 0.97$) and jump performance (SMD = 0.43, 95% CI [−0.03, 0.88], $p = 0.06$), there were no significant differences between cluster training and traditional RT. Cluster training has additional advantages in improving short-distance sprint performance in athletes; however, its effects on strength, agility, and jump performance remain unclear. Future studies should further investigate optimisation strategies for cluster training and its potential applications for enhancing sport-specific performance across different athletic populations.

***Keywords**: strength; jump performance; sprint; agility*

Introduction

Resistance training (RT) is a widely used strength-training method that involves systematic manipulation of training load, volume, and rest intervals to promote adaptations in strength, muscle hypertrophy, and muscular endurance, thereby contributing to enhanced athletic performance (Ahtiainen et al., 2020; Kraemer and Ratamess, 2004). However, because RT typically involves relatively high training loads, inadequate management of training load and recovery may lead to fatigue accumulation and increase the risk of sport-related injuries in athletes (Faigenbaum et al., 2011). Therefore, optimizing resistance-training set configurations to enhance performance-related adaptations while minimizing fatigue accumulation and injury risk remains an important issue in strength and conditioning practice.

Cluster training is a modified form of RT that manipulates intra-set rest intervals and set configurations (Iglesias-Soler et al., 2016). Common cluster-set configurations include inter-repetition rest, rest redistribution, rest-pause structures, and approaches incorporating isometric holds during intra-set rest (Zhong et al., 2024). The main feature of cluster training is that it extends recovery periods within a set, thereby facilitating the resynthesis of high-energy phosphates, particularly adenosine triphosphate (ATP) and phosphocreatine (PCr), while promoting metabolite clearance (Denton and Cronin, 2006).

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This may help maintain higher power output throughout training sessions (Tufano et al., 2017). In addition, cluster training may attenuate lactate accumulation (Girman et al., 2014), metabolic stress, and fatigue during high-load resistance training (Mora-Custodio et al., 2018). Theoretically, by altering the acute training stimulus, cluster training may ultimately induce adaptive responses related to strength development and muscle hypertrophy (Haff et al., 2008a).

Although recent studies have shown that cluster training produces effects comparable to those of traditional resistance training on muscular strength, hypertrophy, and power output (Davies et al., 2021), most available evidence has been derived from untrained or recreationally trained individuals. Therefore, the effectiveness of cluster training in athletes, including high-level athletes, amateur athletes, and sport participants, remains insufficiently established. In untrained or recreationally trained individuals, owing to their relatively low level of physical activity, variables of neuromuscular functioning may show similar adaptive improvements regardless of the set configuration used (Davies et al., 2021). However, following prolonged structured training, athletes may experience attenuated adaptive responses and performance plateaus. Owing to its distinctive manipulation of intra-set rest intervals and set configuration, cluster training may offer a practical strategy for overcoming stagnation in sport-specific performance (Berthelot et al., 2015; Davies et al., 2021). High-level athletes may require more precise manipulation of training variables, such as volume, load, rest intervals, and set configuration, to elicit further muscular and neural adaptations (Nagatani et al., 2022). A progressive cluster training model that systematically increases training intensity or the overall training stimulus may provide a practical strategy for enhancing sport-specific performance in athletes (Spieszny et al., 2026). Athletes seeking to improve performance in a specific sport may therefore benefit from incorporating cluster training into their training programmes. However, the heterogeneous participant populations included in existing studies limit the accurate evaluation of the benefits of cluster training. Previous reviews have primarily focused on the effects of cluster training on maximal strength and peak power, with limited attention given to more sport-specific performance outcomes, such as short-distance sprint, agility, and jump performance. Thus, the limitations of available research, together with variability in study populations and training programmes, highlight the need for an updated and more comprehensive analysis.

In light of these limitations in the existing literature, the present study aimed to conduct a systematic review and meta-analysis to evaluate the effects of cluster training on maximal strength, sprint, agility, and jump performance in athletes, as well as to estimate pooled effect sizes and explore potential moderating factors. This meta-analysis will help address an important gap in the literature by synthesising evidence on the effects of cluster training on sport-specific performance outcomes in athletes. The findings may provide evidence-informed guidance for coaches as well as strength and conditioning practitioners when designing training programmes.

Methods

Experimental Approach to the Problem

The study strictly followed the requirements of Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020, and the protocol registration was completed on the PROSPERO platform (registration number: CRD42024547100).

Data Sources and Search Strategy

The PubMed, Web of Science, Cochrane Library, Embase, and CNKI databases were systematically searched for randomised controlled trials (RCTs) on the effects of cluster training on sports performance from inception to June 2026. The language was restricted to Chinese and English. Searches were conducted using combinations of subject terms and free-text terms with Boolean operators, as follows: ('Cluster training' OR 'Cluster set training' OR 'Cluster structure' OR 'Cluster set') AND ('Athlete' OR 'Professional athletes' OR 'Athlete, professional' OR 'Athletes, professional' OR 'Professional athlete'). In addition, the reference lists of the included studies and relevant reviews were manually screened to identify additional studies that met the inclusion criteria.

Selection Criteria

Type of the Study

All included studies were randomised controlled trials (RCTs).

Participants

This review focused on athletes, including competitive athletes and trained sport participants. Studies were eligible if participants were professional, collegiate, high-school, elite, semi-professional, intramural or recreational athletes, or if they were explicitly described as sport participants with regular training experience.

Interventions

The experimental group included participants who underwent cluster training, whereas the control group comprised participants who received traditional RT. The intervention duration was required to be at least four weeks.

Outcome Indicators

The outcome measures included maximal strength, jump performance, short-distance sprint performance, agility performance, and other sport-specific performance outcomes. Maximal strength was assessed using one-repetition maximum (1RM) tests, whereas vertical jump performance was assessed using the countermovement jump (CMJ). Short-distance sprint performance was assessed using 20-m and 30-m sprint times. Agility performance was assessed using the specific agility tests reported in the included studies. For all included outcomes, baseline and post-intervention means and standard deviations were extracted.

Exclusion Criteria

The following records were excluded: studies that did not meet the inclusion criteria, duplicate publications, conference abstracts, review articles, and reports with incomplete data. Two researchers independently screened the records using EndNote 20. Any disagreements regarding study selection were resolved through discussion with the third researcher.

Data Extraction

Two researchers independently reviewed, assessed, and extracted data from the included studies using a standardised procedure. Extracted information included study population characteristics, such as the athlete type, sample size in the experimental and control groups, age, and sex; intervention characteristics, including intervention content, duration, frequency, and intensity; and outcome data, including means, standard deviations, and changes from baseline to post-intervention. All extracted data were compiled and managed using Microsoft Excel 2016. The extracted data were then compared between the two researchers, and any discrepancies were resolved through discussion with the third researcher.

Studies were eligible for inclusion if outcome data were reported as means and standard deviations (M ± SD) or could be converted into this format. After data extraction, the data were converted into mean change scores and corresponding standard deviations from baseline to post-intervention. The mean change score and its standard deviation were calculated as follows (Li and Meng, 2023):

① $\Delta M = M2 - M1$, where ΔM represented the mean change from baseline to post-intervention, M2 was the post-intervention mean, and M1 was the baseline mean.

② $SD = \sqrt{SD1^2 + SD2^2 - 2R \times SD1 \times SD2}$, SD was the standard deviation of the difference between before and after; SD1 was the standard deviation of the pre-test; SD2 was the standard deviation of the post-test; R was the correlation coefficient, which was set to 0.5.

Literature Quality Assessment

The methodological quality of the included RCTs was assessed using the PEDro scale (Ludyga et al., 2016). The PEDro scale includes the following criteria with respect to the following 10 aspects: (i) 'clear description of eligibility criteria'; (ii) 'random allocation'; (iii) 'concealed allocation'; (iv) 'baseline similarity'; (v) 'exercise load control'; (vi) 'blinding of outcome assessors'; (vii) 'outcome data obtained from more than 85% of participants'; (viii) 'intention-to-treat analysis'; (ix) 'between-group comparisons'; and (x) 'reporting of point estimates and measures of variability'.

Each fulfilled criterion was awarded 1 point, with a maximum possible score of 10 points. Studies scoring <4, 4–5, 6–8, and 9–10 points were classified as of low, moderate, high, and very high methodological quality, respectively.

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Statistical Analysis

Statistical analyses were performed using the meta and metafor packages in R software, version 4.2.0 (Viechtbauer, 2010). Effect sizes were pooled using a random-effects model with inverse-variance weighting. Between-study variance was estimated using the DerSimonian-Laird method. The standardised mean difference (SMD) was selected as the effect-size metric, and pooled effects were reported with 95% confidence intervals (CIs). The magnitude of the absolute SMD values was interpreted as follows: <0.2, trivial effect; 0.2–0.5, small effect; 0.5–0.8, moderate effect; and >0.8, large effect. Statistical significance was set at $p < 0.05$. Heterogeneity among the included studies was assessed using the I^2 statistic. I^2 values were interpreted as follows: 0–25%, non-significant heterogeneity; 26–50%, moderate heterogeneity; 51%–75%, significant heterogeneity; and 76–100%, very high heterogeneity. Subgroup analyses were performed to explore potential sources of heterogeneity (Higgins and Thompson, 2002).

Results

Literature Search Results

The database search identified 1,004 records related to cluster training. After removal of duplicates, 925 records remained for screening. Title and abstract screening resulted in 53 articles being selected for full-text assessment, of which 12 studies met the inclusion criteria. Three additional studies were identified through manual screening of reference lists. Therefore, a total of 15 studies were included in the meta-analysis (Figure 1).

Basic Characteristics of the Included Literature

Table 1 summarises the characteristics of the included studies. The 15 selected studies were published between 2011 and 2024 (Aravena-Sagardia et al., 2021; Arazi et al., 2018, 2021; Chen, 2018; CiN et al., 2021; Cuevas-Aburto et al., 2021; Ersöz et al., 2022; Hansen et al., 2011; Korak et al., 2017; Nicholson et al., 2016; Oliver et al., 2013; Zaras et al., 2020, 2022; Zarezadeh-Mehrizi et al., 2013; Zilong Chen and Yuhua Gao, 2023). All included studies examined the effects of cluster training on sport-specific performance outcomes in athletes, including maximal strength, short-distance sprint performance, jump and agility performance. The most commonly used resistance exercises were squats, bench presses, deadlifts, and leg presses. Training intensity ranged from 30% to 95% of the one-repetition maximum (1RM), and intervention duration ranged from 4 to 10 weeks. The main outcome measures included the 1RM squat, the 1RM bench press, 20-m and 30-m sprint performance, the countermovement jump (CMJ), and the agility T-test. The participant samples across the 15 included studies comprised athletes from several sports, including soccer, shot put, volleyball, basketball, rugby, weightlifting, and badminton, as well as resistance-trained individuals, physical education students, and trained military personnel.

Quality Assessment of the Included Literature

The PEDro scores of the 15 included studies ranged from 5 to 8, with a mean score of 7.3, indicating high overall methodological quality (Table 2). All studies reported 'clear description of eligibility criteria', 'between-group comparisons', 'reporting of point estimates and measures of variability', and 'exercise load control'. Ten papers met the criterion of 'random allocation', 13 papers of 'baseline similarity', 13 papers of 'outcome data obtained from more than 85% of participants', and 12 papers included 'intention-to-treat analysis'; none of the papers reported 'concealed allocation' or 'blinding of outcome assessors'.

Meta-Analysis of Cluster Training and Short-Distance Sprint Performance

Five studies assessed the effects of cluster training on short-distance sprint performance, mainly using 20-m and 30-m sprint tests, and provided eight intervention-control comparisons. To avoid double-counting of participants and to maintain the independence of effect sizes, only one sprint outcome was selected from each study when multiple identical or similar outcomes were reported. The meta-analysis showed that cluster training significantly improved short-distance sprint performance in athletes compared with RT, and the difference was statistically significant (SMD = −0.44, 95% CI [−0.88, 0.00], $p < 0.05$). No statistically significant heterogeneity was observed in the pooled analysis ($I^2 = 28.6\%$, $p = 0.23$) (Figure 2).

For the subgroup analyses, intervention duration was categorised as <8 weeks or ≥8 weeks, and training modality was categorised as

combined upper- and lower-limb training or lower-limb training only (Table 3). For interventions lasting <8 weeks, the pooled effect favoured cluster training for improving short-distance sprint performance in athletes (SMD = −0.660, 95% CI [−1.113, −0.207], p = 0.152). Heterogeneity was moderate and non-significant (I^2 = 46.94%). For interventions lasting ≥8 weeks, cluster training did not show a statistically significant effect on short-distance sprint performance in athletes (SMD = −0.105, 95% CI [−0.675, 0.464], p = 0.815). No between-study heterogeneity was observed (I^2 = 0%).

In the combined upper- and lower-limb training subgroup, cluster training showed a statistically significant effect on short-distance sprint performance in athletes (SMD = −0.688, 95% CI [−1.264, −0.111], p = 0.035). Heterogeneity was considerable (I^2 = 77.46%). In the subgroup involving lower-limb training only, the pooled effect did not indicate a statistically significant benefit for short-distance sprint performance in athletes (SMD = −0.298, 95% CI [−0.747, 0.151], p = 0.768). No heterogeneity was observed in this subgroup (I^2 = 0%).

Meta-Analysis of Cluster Training and Maximal Strength

Fifteen studies examined the effects of cluster training on maximal strength, including 1RM squat, 1RM bench press, and 1RM leg press outcomes, and provided 25 intervention-control comparisons. To avoid double-counting of participants and maintain the independence of effect sizes, only one strength outcome was selected from each study when multiple identical or similar outcomes were reported. The meta-analysis showed no statistically significant effect of cluster training on maximal strength in athletes compared with traditional RT (SMD = 0.00, 95% CI [−0.23, 0.22], p = 0.97). No between-study heterogeneity was observed (I^2 = 0%, p = 0.55) (Figure 3).

Meta-Analysis of Cluster Training and Jump Performance

Seven studies assessed the effects of cluster training on jump performance, mainly using countermovement jump (CMJ) tests, and provided eight intervention-control comparisons. To avoid double-counting of participants and maintain the independence of effect sizes, only one jump outcome was selected from each study when multiple identical or similar outcomes were provided. The meta-analysis showed that cluster training did not produce a statistically significant improvement in jump performance compared with traditional RT (SMD = 0.43, 95% CI [−0.03, 0.88], p = 0.07). Additionally, moderate between-study heterogeneity was observed (I^2 = 48.4%, p = 0.07) (Figure 4).

Meta-Analysis of Cluster Training and Agility Performance

Three studies examined the effects of cluster training on agility performance, with outcomes assessed using the 9-m shuttle test, the IAI agility test, and the agility T-test. Meta-analysis showed that cluster training tended to improve agility performance in athletes compared with RT, however, the between-group difference was not statistically significant (SMD = −0.82, 95% CI [−2.29, 0.65], p = 0.24). Considerable between-study heterogeneity was observed in the pooled analysis (I2 = 87.1%, p < 0.01) (Figure 5).

Discussion

This systematic review and meta-analysis investigated the effects of cluster training on sports performance including short-distance sprint performance, jump performance, maximal strength and agility in athletes. The results showed that, compared with traditional resistance training, cluster training provided greater benefits for short-distance sprint performance, whereas no significant differences were observed between the two training approaches for maximal strength, agility or jump performance. Subgroup analyses indicated that combined upper- and lower-limb training appeared to be more effective than lower-limb training only for improving short-distance sprint performance in athletes. These findings provide practical insights into the application of cluster training in strength and conditioning programmes.

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Table 1a. Characteristics of studies included in the present review.

Studies	Population (type of athletes, N, sex, age)	Resistance exercise(s)	Training intensity	RT and CT set configuration		Training frequency/ length	Outcomes
				Sets and repetitions	Inter-set and intra-set rest intervals		
Ersöz et al. (2020)	Soccer players, N = 32, M, 18.78 ± 0.83 yrs	hip thrust, squat	50–80% 1RM	3 × 8	CT: 180 s/20 s RT: 180 s/NA	2 times/week, 4 weeks	①④⑥⑨⑩
Hansen et al. (2011)	Rugby players, N = 18, M, 26.8 ± 4.5 yrs	squat, deadlift, box squat, power clean	80–95% 1RM	5 × (3–6)	CT: 180 s /20–30 s RT: 180 s/NA	4 times/week, 8 weeks	①
Arazi et al. (2018)	Volleyball players, N = 20, F, 18.5 ± 4.2 yrs	squat, bench press, deadlift,, jump squat, clean and jerk	30–80% 1RM	(1–3) × (1–10)	CT: 120–180 s/20–30 s RT: 120–180 s/NA	3 times/week, 8 weeks	①②④⑨
Cin et al. (2021)	Volleyball players, N = 28, M, 27.3 ± 1.5 yrs	squat	85% 1RM	3 × 6	CT: 80 s/20 s RT: 120 s/20 s	3 times/week, 6 weeks	①②④⑦⑧
Nicholson et al. (2016)	trained individuals, N = 23, M, 21.76 ± 2.60 yrs	squat	85% 1RM	4 × 6	CT: 300 s/25 s RT: 300 s/NA	3 times/week, 6 weeks	①⑦
Cuevas-Aburto et al. (2021)	shot put athletes, N = 26, M, 20.7 ± 2.8 yrs	bench press	75% 1RM	CT: 1 × 30 RT: 6 × 5	CT: 0/31 s RT: 30 s/NA	2 times/week, 6 weeks	②
Arazi et al. (2021)	weightlifting athletes, N = 16, M, 23.5 ± 1.1 yrs	squat, bench press, deadlift	70–85% 1RM	CT: 1 × (8–10) RT: 2 × (4–5)	CT: 120 s /20–30 s RT: 120 s/NA	2 times/week, 8 weeks	①②
Oliver et al. (2013)	trained military personnel, N = 22, M, 25.0 ± 5.0 yrs	squat, bench press	60–75% 1RM	CT: (3–4) × (5–10) RT: (4–8) × 10	CT: 60–120 s/60–120 s RT: 60–120 s/NA	4 times/week, 12 weeks	①②
Zarezadeh et al. (2013)	Soccer players, N = 22, M, 24.7 ± 3.1 yrs	squat	85% 1RM	3 × 5	CT: 120 s /10–30 s RT: 180 s/NA	3 times/week, 6 weeks	①
Zaras et al. (2020)	University basketball players, N = 16, M, 22.7 ± 4.8 yrs	squat	85% 1RM	4 × 6	CT: 180 s/20 s RT: 180 s/NA	2 times/week, 7 weeks	③
Korak et al. (2017)	Trained individuals, N = 20, M, 23.1 ± 2.3 yrs	bench press	80% 1RM	4/8	CT: 120 s/32 s RT: 120 s/NA	2 times/week, 4 weeks	②
Zaras et al. (2022)	University volleyball players, N = 16, M, 22.7 ± 4.8 yrs	bench press	85% 1RM	4/6	CT: 180 s/20 s RT: 180/NA	2 times/week, 7 weeks	②

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Table 1b. Characteristics of studies included in the present review.

Studies	Population (type of athletes, N, sex, age)	Resistance exercise(s)	training intensity	RT and CT set configuration		Training frequency/ length	Outcomes
				Sets and repetitions	Inter-set and intra-set rest intervals		
Aravena-Sagardia et al. (2021)	Trained individuals, N = 16, M, 19.0 ± 1.2 yrs	bench press, squat, deadlift	70–85% 1RM	3 × 5	CT: 90 s/30 s RT: 90 s/NA	2 times/week, 8 weeks	②⑥
Chen et al. (2018)	University endurance athletes, N = 16, M, 19.8 ± 1.5 yrs	squat	60–75% 1RM	4 × (5+5)	CT: 90 s/30 s RT: 120 s/NA	2 times/week, 8 weeks	①⑦⑨
Chen et al. (2021)	Badminton players, N = 24, M, 15.2 ± 1.3 yrs	squat	80% 1RM	CT: 4 × (3+3) RT: 4 × 6	CT: 90 s/30 s RT: 120 s/NA	2 times/week, 6 weeks	①⑤⑥

Note: N = number, M = male, F = female, yr. = years, 1RM = one repetition maximum, CT = Cluster training, RT = Resistance training, s = seconds, N/A = not applicable ① 1RM squat; ② 1RM bench press; ③ 1RM leg press; ④ 20-m sprint; ⑤ 30-m sprint; ⑥ CMJ: countermovement jump; ⑦ standing long jump; ⑧ T-test: a method of agility testing; ⑨ 9-m shuttle test; ⑩ IAI intermittent agility test;

Table 2. Methodological quality assessment of the included studies.

Studies	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	Total points
Ersöz et al. (2020)	1	1	0	1	1	0	1	1	1	1	8
Hansen et al. (2011)	1	1	0	1	1	0	1	1	1	1	8
Arazi et al. (2018)	1	1	0	1	1	0	1	1	1	1	8
CiN et al. (2021)	1	1	0	1	1	0	1	1	1	1	8
Nicholson et al. (2016)	1	0	0	1	1	0	0	0	1	1	6
Cuevas-Aburto et al. (2021)	1	1	0	1	1	0	1	0	1	1	7
Arazi et al. (2021)	1	1	0	1	1	0	1	1	1	1	8
Oliver et al. (2013)	1	0	0	1	1	0	1	1	1	1	7
Zarezadeh et al. (2013)	1	0	0	1	1	0	1	1	1	1	7
Zaras et al. (2020)	1	0	0	0	1	0	1	1	1	1	6
Korak et al. (2017)	1	1	0	1	1	0	1	1	1	1	8
Zaras et al. (2022)	1	0	0	1	1	0	1	1	1	1	7
Aravena-Sagardia et al. (2021)	1	1	0	0	1	0	0	0	1	1	5
Chen Wenjia et al. (2018)	1	1	0	1	1	0	1	1	1	1	8
Chen Zilong et al. (2021)	1	1	0	1	1	0	1	1	1	1	8

Note: ① 'clear description of eligibility criteria', ② 'random allocation', ③ 'concealed allocation', ④ 'baseline similarity', ⑤ 'exercise load control', ⑥ 'blinding of outcome assessors', ⑦ 'outcome data obtained from more than 85% of participants', ⑧ 'intention-to-treat analysis', ⑨ 'between-group comparisons', ⑩ 'reporting of point estimates and measures of variability'

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Table 3. Subgroup analyses of the effects of cluster training on short-distance sprint performance in athletes.

Subgroup	Categorisation	Studies/comparisons	n	SMD	95%CI	I^2/%
Intervention duration	≥8 weeks	2	44	−0.105	[−0.675, 0.464]	0
	<8 weeks	3	76	−0.660	[−1.113, −0.207]	46.94
Training modality	Upper- and lower-limb training	2	48	−0.688	[−1.264, −0.111]	77.46
	Lower-limb training only	3	72	−0.298	[−0.747, 0.151]	0

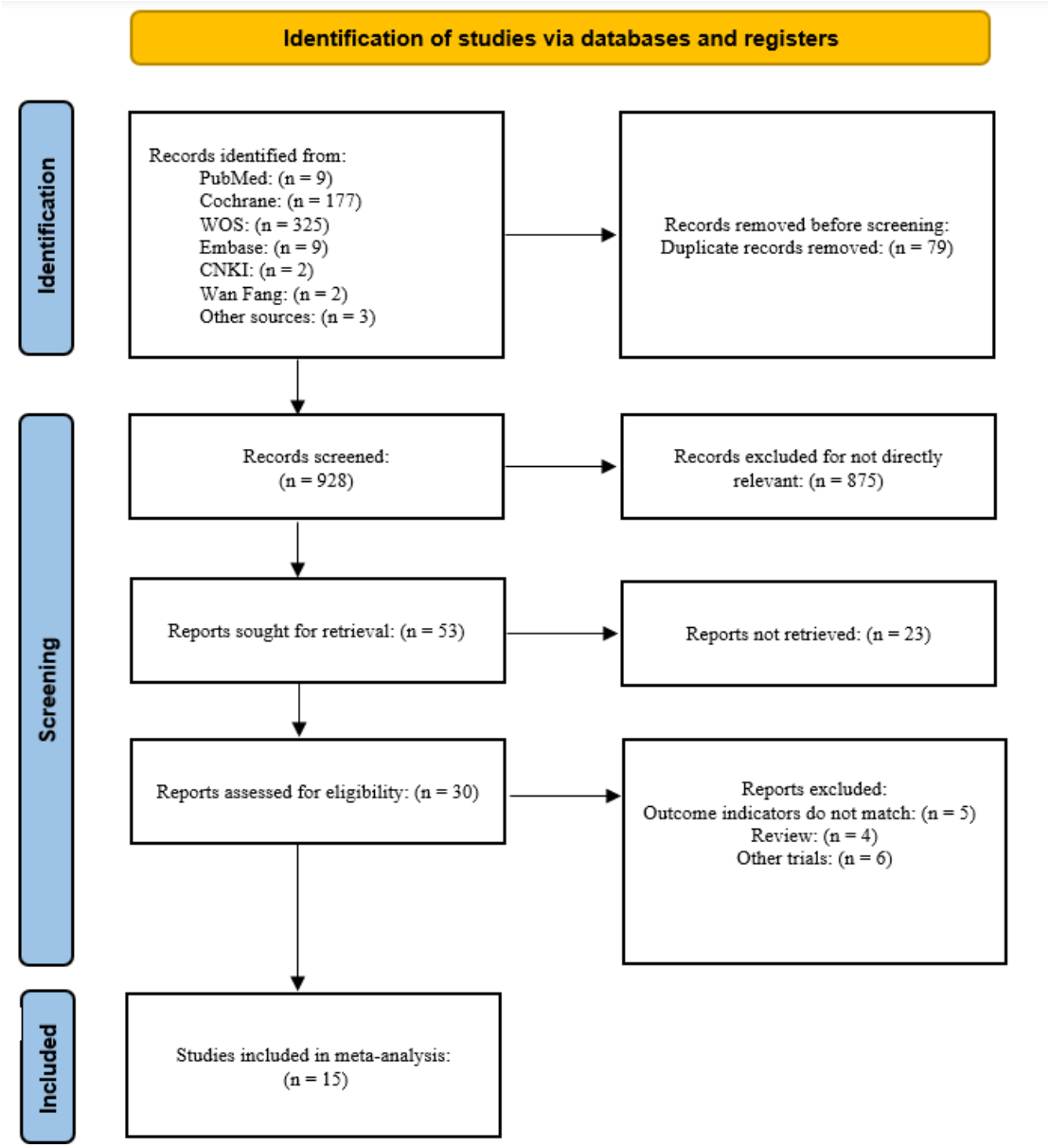


Figure 1. Flow chart of literature screening.

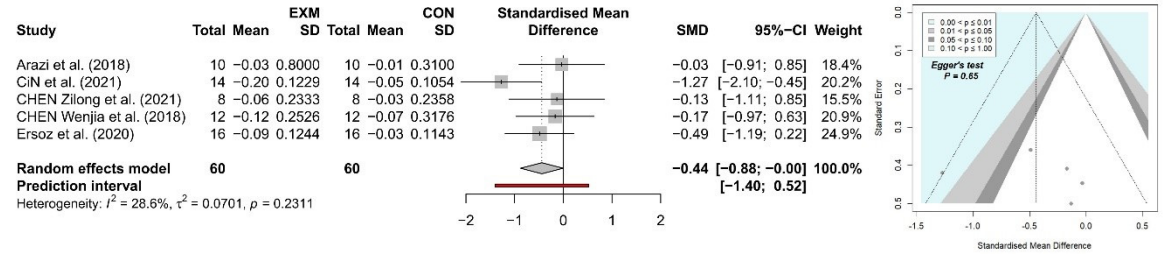


Figure 2. Forest plot and the funnel plot of the effect of cluster training on short-distance sprint performance in athletes.

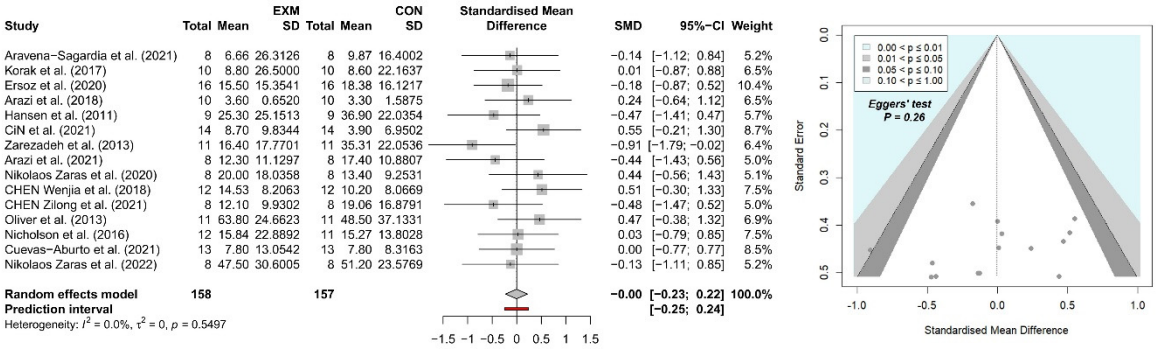


Figure 3. Forest plot and the funnel plot of the effect of cluster training on the maximum strength of athletes.

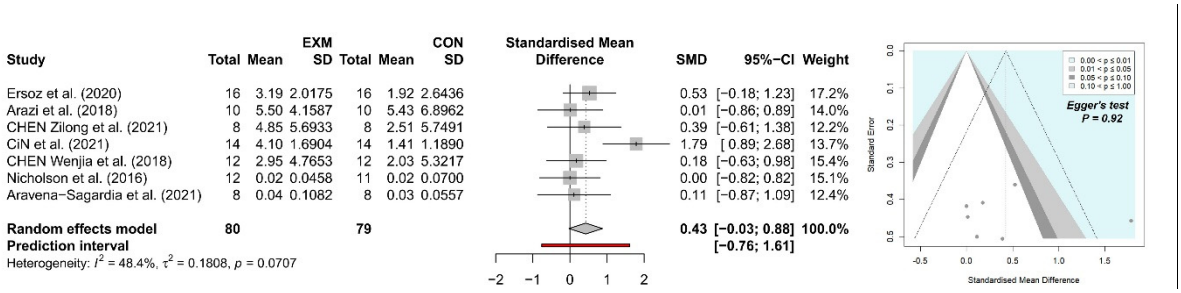


Figure 4. Forest plot and the funnel plot of the effect of cluster training on jump performance of athletes.

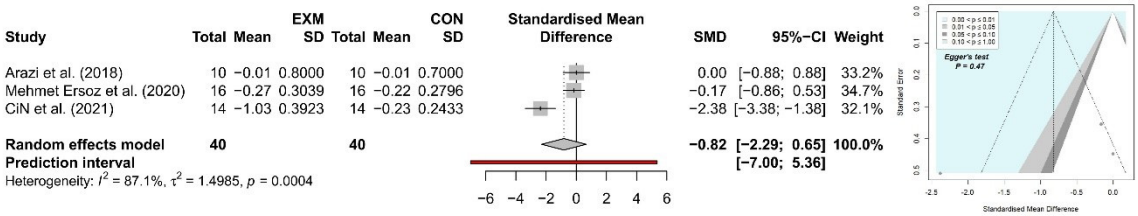


Figure 5. Forest plot and the funnel plot of the impact of cluster training on agility performance of athletes.

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The Effects of Cluster Training on Short-Distance Sprint Performance in Athletes

The meta-analysis showed that cluster training was more effective than traditional RT in improving short-distance sprint performance in athletes. All five studies (Arazi et al., 2018; Chen, 2018; Cin et al., 2021; Ersöz et al., 2022; Chen and Gao, 2023) included in the meta-analysis reported greater improvements in short-distance sprint performance following cluster training than traditional RT, with consistent findings across studies. Studies by Cin et al. (2021), Ersöz et al. (2022) and Chen et al. (2018) reported significant improvements in short-distance sprint performance, whereas Arazi et al. (2018) and Chen et al. (2023) reported relatively smaller improvements. Further examination of the two studies reporting smaller improvements in short-distance sprint performance showed that the mean participant age in these studies was 18.5 ± 4.2 and 15.2 ± 1.3 years, respectively. Most participants in both studies were adolescent athletes. Less mature neuromuscular function and lower Achilles tendon stiffness in adolescent athletes may contribute to a longer time to reach peak force production than in adults, which could negatively affect sprint performance (Chatzilazaridis et al., 2024). Additionally, adolescents aged 16–18 years are characterised by non-linear growth and development, with substantial inter-individual variation in musculoskeletal maturity, which may affect their sport-specific performance (Castillo et al., 2020). Therefore, athletes' age and training experience may be important factors influencing the effectiveness of cluster training for improving short-distance sprint performance. Previous research by Asadi and Ramírez-Campillo (2016) reported that cluster training and traditional RT produced comparable effects on short-distance sprint performance, which may be related to the participants' motor skill level and technical proficiency (Lu et al., 2026). In the present review, most participants in the included studies had prior training experience and relatively high levels of technical proficiency and physical fitness. These characteristics may have reduced the influence of inter-individual variability, thereby allowing a more accurate evaluation of the effects of cluster training on sport performance in athletes. Regarding the physiological mechanisms underlying the effects of cluster training on sprint performance, short-distance sprinting relies primarily on the phosphagen system for ATP resynthesis (Brooks and Gladden, 2003). In contrast, repeated high-intensity resistance exercise increases reliance on glycolytic metabolism (Ulupınar et al., 2021). By extending inter-repetition rest periods, cluster training may attenuate glycolytic contribution, facilitate H^+ clearance, help maintain intracellular pH, and promote the resynthesis of high-energy phosphates, particularly adenosine triphosphate (ATP) and phosphocreatine (PCr) (Hansen et al., 2011; Korak et al., 2017). These responses may help preserve movement velocity, power output, and force production across repetitions (Girman et al., 2014; Tufano et al., 2017). Collectively, these mechanisms can help optimise the force-velocity characteristics that are critical for short-distance sprint performance. Furthermore, by incorporating intra-set rest intervals, cluster training may attenuate fatigue accumulation and help athletes maintain movement quality, velocity, and power output across repetitions. Over time, these training conditions may promote neuromuscular adaptations that contribute to improved short-distance sprint performance (Arazi et al., 2021; Morin et al., 2012).

To further examine the effects of cluster training on short-distance sprint performance in athletes, subgroup analyses were conducted. The results suggested that combined upper- and lower-limb training was more effective than lower-limb training only for improving sprint performance. This may be explained by the fact that effective sprinting requires coordinated and synchronised actions of the upper and lower limbs, while upper-body strength and arm mechanics may contribute to sprint-related power output (Macadam et al., 2018; Sandbakk et al., 2015). Therefore, upper-body strength development should be considered when designing training programmes aimed at improving sprint and overall athletic performance.

The Effects of Cluster Training on Athletes' Maximal Strength

The meta-analysis showed no significant difference between cluster training and traditional RT in improving maximal strength in athletes. This finding is consistent with the previous review by Davies et al. (2021), which reported comparable effects of cluster training and traditional RT on

strength outcomes, although 12 of the 26 included comparisons involved untrained or recreationally trained individuals. By contrast, the present review included 15 studies focusing specifically on trained athletes and sport participants, yet no significant difference between cluster training and traditional RT was observed. Nevertheless, seven studies (Aravena-Sagardia et al., 2021; Arazi et al., 2021; Chen and Gao, 2023; Ersöz et al., 2022; Hansen et al., 2011; Zaras et al., 2022; Zarezadeh-Mehrizi et al., 2013) reported greater improvements in maximal strength following traditional RT than after cluster training. One possible explanation is that the greater metabolic stress and fatigue associated with traditional RT may contribute to strength-related neuromuscular adaptations through the following mechanisms: (1) the cluster-set structure allows partial intramuscular phosphocreatine (PCr) resynthesis during intra-set rest periods, thereby supporting metabolic recovery and helping to maintain movement quality and force output (Girman et al., 2014). However, maximal strength adaptations may also be partly supported by greater metabolite accumulation and metabolic stress. In traditional RT, continuous repetitions without intra-set rest may increase time under tension and metabolite accumulation, which could contribute to strength-related neuromuscular adaptations (Hansen et al., 2011); (2) motor-unit recruitment and synchronisation are important neural factors underlying the development of maximal strength (Suchomel et al., 2018). Maximal strength adaptations may be partly mediated by the recruitment of high-threshold motor units, and metabolic fatigue may further increase the recruitment of these motor units to maintain force output (Haff et al., 2008b); (3) traditional RT is characterised by continuous repetitions with limited intra-set recovery; therefore, it may induce greater accumulation of lactate and other fatigue-related metabolites within working muscles. Lactate accumulation is considered an important contributor to muscle growth, and increased intracellular acidity may help promote hypertrophic and strength-related adaptations (Pearson and Hussain, 2015). Therefore, traditional RT may produce greater maximal-strength gains than cluster training in some contexts. However, other studies have suggested that cluster training may also be beneficial for maximal-strength development. These inconsistent findings suggest that maximal-strength adaptations may be influenced not only by fatigue and metabolite accumulation, but also by neuromuscular, mechanical, recovery-related, and hormonal factors (Folland et al., 2002; Haff et al., 2008a). In this context, cluster training may influence acute hormonal responses, including growth hormone and cortisol, by altering intra-set recovery and training stress (Wongsason and Apanukul, 2021). However, these acute hormonal responses should be interpreted as potential modulators or physiological markers of training adaptation rather than direct determinants of strength gains.

In summary, the present review found no significant difference between cluster training and traditional RT in improving maximal strength in athletes. This finding may be partly explained by variability in participant characteristics, training protocols, and intervention content, all of which may influence neuromuscular, mechanical, and metabolic adaptations. Although the current evidence suggests that the effects of cluster training and traditional RT on maximal strength are broadly comparable, the mechanisms underlying these adaptations remain unclear. Further research is therefore needed to clarify the physiological mechanisms and practical effectiveness of cluster training for improving maximal strength in athletes.

The Effects of Cluster Training on the Jump Performance in Athletes

The meta-analysis showed that the difference between cluster training and traditional RT in improving jump performance in athletes did not reach statistical significance. However, the pooled effect showed a non-significant trend favouring cluster training ($p = 0.07$), and six of the seven included studies reported greater improvements in jump performance following cluster training than following traditional RT. This finding is consistent with the previous study by Jukic et al. (2021). Jukic et al. (2021) reported that cluster training showed a small, non-significant advantage over traditional RT for improving vertical jump performance (SMD = 0.13). They suggested that this may be partly explained by the insufficient jump-specificity of the training interventions. Vertical jump performance is a complex explosive movement that requires

coordinated neuromuscular adaptations rather than a strength-training stimulus alone (Young et al., 2015). Further examination of the included studies indicated that most interventions were strength-oriented, whereas relatively few incorporated jump-specific components targeting explosive strength, rate of force development, and neuromuscular coordination. In the study by Rong and Xiu (2024), 16 well-trained volleyball players completed a 6-week CS-COX intervention, a complex cluster-training model that combined strength training with explosive training to improve vertical jump performance. The authors reported that cluster training produced greater benefits than traditional RT for vertical jump performance (ES = 0.36). Taken together, these findings suggest that the lack of jump-specific training content may be an important factor limiting the statistical significance of intervention effects in previous studies (Li et al., 2026). The potential physiological mechanisms by which cluster training improves jump performance may be related to its ability to redistribute rest within sets. This structure may facilitate phosphocreatine (PCr) resynthesis, attenuate lactate and metabolite accumulation, and reduce perceived fatigue, thereby helping athletes maintain movement velocity, power output, and explosive performance during training. These mechanisms may be particularly relevant for jump performance and other power-based performance outcomes (Morales-Artacho et al., 2018).

In summary, existing evidence suggests that cluster training may provide greater benefits than traditional RT for improving jump performance in athletes, although the magnitude of the intervention effect appears to be influenced by the specificity of the training content. Future studies should incorporate vertical jump-specific components into comprehensive strength-training programmes to improve training specificity and more accurately evaluate the effects of cluster training on jump performance in athletes.

The Effects of Cluster Training on Agility Performance in Athletes

The meta-analysis showed that cluster training did not demonstrate a statistically significant advantage over traditional RT in improving agility performance in athletes. A closer examination of the included studies showed that two of the three studies reported significant improvements in agility performance following cluster training (CïN et al., 2021; Ersöz et al., 2022). In contrast, Arazi et al. (2018) reported comparable effects of cluster training and traditional RT on agility performance in athletes. Several factors may explain this considerable heterogeneity observed across studies. First, the methods used to assess agility after the training interventions varied across studies, as pre-planned change-of-direction tasks and reactive agility tasks may involve different neuromuscular, biomechanical, and perceptual-cognitive demands (Shi et al., 2026). In particular, Arazi et al. (2018) included only young female athletes, with relatively low baseline strength levels, as indicated by 1RM squat values below 50 kg. Regarding the physiological mechanisms underlying the effects of cluster training on agility performance, Cin et al. (2021) suggested that the intra-set rest intervals used in cluster training may facilitate the resynthesis of high-energy phosphates, particularly ATP and PCr, while accelerating metabolite clearance and attenuating fatigue accumulation. These mechanisms may help athletes maintain movement velocity and technical quality during repeated high-intensity efforts, thereby supporting neuromuscular adaptations relevant to change-of-direction and agility performance. Ye et al. (2022) reported a strong association between agility and speed-related qualities, suggesting that improvements in short-distance sprint performance may positively influence agility performance in athletes. This may partly explain the non-significant trend favouring cluster training over traditional RT for agility performance. However, the small number of studies included in the analysis may have limited the statistical power and robustness of the findings. In addition, the intervention programmes included in the analysis were based on heavy-load resistance training and lacked agility-specific training components (Eler et al., 2026). Agility performance is influenced by multiple factors, including body mass, perceptual ability, technical proficiency, and maximal strength (Paul et al., 2016). Therefore, the limited inclusion of agility-specific training content may have reduced the precision of the estimated effects and introduced uncertainty regarding the true effectiveness of cluster training for improving agility.

Future research should conduct large-

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sample, high-quality RCTs and develop cluster training models specifically designed to improve agility, thereby enabling a more accurate evaluation of the effects of cluster training on agility performance in athletes.

Limitations

The present review has several limitations. First, among the 15 included studies, most participants were male athletes, and only two studies included female athletes (Aravena-Sagardia et al., 2021; Arazi et al., 2018). Female athletes accounted for only a small proportion of the total sample (8%). Therefore, sex-specific effects were not examined in detail, and the under-representation of female participants may have limited the interpretation of outcomes such as strength and speed. Second, most included studies did not report participants' training experience, and differences in training background may have influenced the accuracy of the findings. Third, agility is a multidimensional performance outcome involving multiple physical, technical, and perceptual factors. The small number of studies included in the agility analysis may therefore limit the robustness of the conclusions for this outcome. Finally, the limited variety and specificity of training content across the included studies may have affected the reliability and generalisability of the findings when evaluating the effects of cluster training on overall sport-specific performance.

Therefore, future studies should include more female participants, better balance participants' training levels, incorporate a broader range of sport performance outcomes, and develop diversified training approaches tailored to the demands of different sports. In addition, periodised cluster-training programmes should be designed to provide a more robust evidence base for evaluating the effects of cluster training on sport-specific performance in athletes.

Conclusions

Cluster training is an effective approach for improving short-distance sprint performance in athletes, and combined upper- and lower-limb training appears to provide greater benefits than lower-limb training only. No significant differences were observed between cluster training and traditional resistance training in maximal strength, agility or jump performance. Further high-quality studies are needed to confirm these findings. Overall, the findings support the incorporation of cluster training into athletes' training programmes, particularly for optimising short-distance sprint performance.

Practical Implications

Cluster training provides an effective approach for enhancing selected aspects of sport-specific performance. To maximise its practical benefits, cluster-training protocols should be developed according to the demands of the specific sport, with the intra-set rest structure and training content adapted to the athlete's training goals and training level. Compared with traditional resistance training, cluster training offers a valuable variation in the training programme design by providing distinct physiological and psychological stimuli and reducing training monotony. However, it should not be considered a replacement for traditional resistance training in all contexts.

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