

Review

Effect of Complex Contrast Training on Change of Direction Performance in Team-Sport Athletes: A Meta-Analysis

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Abstract

(1) Background: Change of direction (COD) is crucial for agility in team sports. Complex contrast training (CNT), alternating between heavy and light exercises, is a newer method currently gaining attention, but its effectiveness compared to others (strength training, ST; plyometric training, PT; complex descending training, DT; complex ascending training, AT) is unclear. (2) Methods: A systematic review and meta-analysis following PRISMA guidelines included studies with CNT interventions. The effect size (ES) was measured using Hedges' *g*, with subgroup analyses for moderating factors. (3) Results: CNT improved COD performance more than PT (ES = 0.65), ST (ES = 0.88), and controls (ES = 1.24), with no significant difference from DT (ES = −0.08) or AT (ES = 0.19). CNT was particularly effective for athletes under 18 (ES = 1.13), females (ES = 1.59), amateurs (ES = 1.02), and COD measures with more than three turns (ES = 1.08). (4) Conclusions: CNT enhances COD performance, proving superior to standalone strength or plyometric training. However, its effectiveness is comparable to other combined-training models, suggesting that the integration of high-load strength and high-velocity power exercises is the primary driver of adaptation. The benefits are most pronounced in younger, female, and amateur athletes. Future large-scale studies are needed to confirm these findings and refine protocols for diverse populations.



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Keywords: complex contrast training; strength training; plyometric training; agility; COD

1. Introduction

Change of direction (COD) is a fundamental aspect of agility, characterized by the ability to decelerate, alter the direction of movement, and then reaccelerate towards a new target [1]. While agility as a whole is heavily influenced by cognitive processes, COD specifically emphasizes the physical components of agility, without requiring a reaction to an external stimulus [2]. COD has been extensively studied across athlete populations and found to be important in a wide range of sports [3]. For example, changing direction using quick accelerations and decelerations ($>2 \text{ m/s}^2$) is found to contribute to soccer players' performance significantly [4]. Similarly, in basketball, the ability to rapidly change direction is crucial for on-court performance [5], with athletes typically executing 50–60 shifts and CODs in an average game [6].

Strength and conditioning practitioners are continually seeking the most effective training methods for enhancing athletes' COD performance. Previous studies have adopted

different types of training methods to improve COD, including strength training (ST), plyometric training (PT), complex ascending training (AT), and complex descending training (DT) [7–10]. Traditional heavy-resistance strength training leads to gains in maximal strength and power mainly by targeting the force component of the power equation (i.e., power as a function of force and velocity) [11]. However, they do not play a meaningful role in maximal power improvements after one's maximal level of strength is attained [12]. Conversely, research has indicated that utilizing lighter loads in plyometric and ballistic/power exercises enables athletes to achieve greater movement velocities. This, in turn, stimulates specific neural adaptations that enhance the rate of force development (RFD) and boost maximal power output [12].

Complex Contrast Training (CNT) has recently emerged as a training method that aims to improve COD performance [13–16]. However, discrepancies exist in the terminology used to describe these methods [17]. Based on the literature, CNT is described as a training method that alternates between high-load weight exercises and lighter-load power exercises in a set-for-set manner (e.g., pairing squats with countermovement jumps) [18–20]. Complex Descending Training (DT) follows a sequential approach, beginning with high-load strength exercises and then transitioning to lighter-load power exercises [17,21]. Conversely, Complex Ascending Training (AT) reverses this order by starting with lighter-load power exercises and concluding with high-load strength exercises [14,17,22]. If a study labeled the training intervention as AT, but it actually met the criteria for CNT according to our definition, we coded the training method based on our criteria rather than those used in the original article. Several studies have found that CNT could be a promising training method to improve COD, compared to power training or heavy-resistance training alone [8,15,23]. However, other studies revealed no difference between CNT and other training methods (i.e., strength or plyometric training) [13,14,24]. In sum, the potential gains from CNT compared to other training methods remain inconclusive.

This study is the first meta-analysis to systematically synthesize and quantify existing evidence regarding the effectiveness of CNT on improving COD performance among team-sport athletes. It goes beyond a narrative review to provide quantitative estimates and compares CNT with other training methods (i.e., PT, ST, DT, and AT) using meta-analysis. This study also explored possible factors that might alter the effectiveness of CNT intervention through subgroup analyses. Findings from this review may help determine the optimal training method for improving COD among team-sport athletes.

2. Materials and Methods

2.1. Study Design

A systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) [25].

2.2. Study Selection Criteria

Inclusion Criteria: Studies were included in the review if they met the criteria outlines below. (1) Study Design: Multi-arm experimental design, including both randomized and non-randomized trials. (2) Study Subjects: Healthy team-sport athletes without a history of injury. (3) Intervention Type: CNT, which includes both strength training and explosive training (i.e., plyometric/sprint/agility) in the same session, set by set. (4) Intervention Duration: Four weeks or longer. (5) Outcome: COD performance. (6) Article Type: Peer-reviewed publications. (7) Time Window of Search: From the inception of an electronic bibliographic database to 1 May 2025. (8) Language: Articles written in English.

Exclusion Criteria: Studies that meet the above inclusion criteria but fall under any of the following criteria were excluded from this review: (1) Studies that used CNT in

conjunction with creatine or other ergogenic aids associated with the training. (2) Studies with a multi-arm experimental design that did not include a control or comparison group. (3) Interventions that included strength training and explosive training but did not alternate these types of training in the same session set by set.

2.3. Search Strategy

A comprehensive keyword search was conducted across seven electronic bibliographic databases: SPORTDiscus, PubMed, Web of Science, Academic Search Complete, Scopus, CINAHL, and Google Scholar. The search strategy involved combining keywords from two distinct categories. The first category included terms such as “complex training”, “combined training”, “compound training”, “contrast training”, “weight and plyometric training” and “strength and plyometric training”. The second category focused on performance-related outcomes, including “agility”, “change of direction” and “COD”. These keywords were systematically combined to generate a wide range of search queries. After the initial search, the titles and abstracts of the retrieved studies were carefully screened to ensure they met the predefined inclusion criteria. Studies that appeared to be relevant based on their titles and abstracts were then selected for a full-text review to determine their suitability for inclusion in the analysis.

The initial screening of titles and abstracts was conducted independently by two co-authors, who identified studies that warranted full-text evaluation. The level of agreement between the co-authors was quantified using Cohen’s kappa, yielding a value of $\kappa = 0.91$, indicating substantial interrater reliability. Any discrepancies were resolved through direct discussions between the co-authors. Subsequently, the full texts of the selected studies were thoroughly reviewed, and the final set of studies included in the review was jointly determined by the co-authors. In addition to the keyword search, a comprehensive reference search was performed. This involved both backward reference searching (examining the reference lists of the selected full-text studies) and forward reference searching (identifying studies that cited the selected full-text studies). All studies identified through these reference searches were subjected to the same selection criteria as those from the keyword search. This iterative reference search process was repeated until no additional relevant studies were identified.

2.4. Data Extraction

A standardized data extraction form was used to collect methodological, and outcome variables from each included study, including authors, publication year, sample size, age, sex, sport, level, intervention type, intervention intensity, intervention frequency, intervention duration, and COD measures. When the required data were not clearly reported in the studies, the corresponding authors were contacted for the missing information. If no response was obtained within two weeks (after two attempts, each separated by a 72 h interval), or if the requested data were not provided, the study was excluded from further analysis. When the authors did not provide numerical data upon request and the data were only displayed in figures, numerical data were derived from the figures using validated software (WebPlot-Digitizer, version 5.2; <https://apps.automeris.io/wpd/>) (accessed on 10 May 2025) [26]. The software validation showed high accuracy ($r = 0.99$, $p < 0.001$). Two authors performed the data extraction and resolved any discrepancies through face-to-face discussion. If consensus could not be reached, a third author was consulted to finalize the decision.

2.5. Meta-Analysis

Meta-analysis was performed to estimate the pooled effect size of CNT on COD performance. The standardized time of the COD task completion served as the effect size, calculated as Hedges’ g . This metric was specifically chosen to correct for the potential

overestimation bias of Cohen's d in studies with small sample sizes, a key consideration as many of the included studies were based on a small number of participants (e.g., $N < 20$). When comparing the performance of CNT with other training methods, we first calculated the difference in effect size between the CNT group and other training groups (i.e., PT, ST, DT, AT, and control) within each study and then estimated the pooled differences, along with their 95% confidence intervals. All analyses were conducted using Stata 17.0 (StataCorp LLC, College Station, TX, USA). Study heterogeneity was quantified using the I^2 index and the τ^2 statistic. A fixed-effect model (FE) was estimated when $I^2 \leq 50\%$, and a random-effect model (RE) was estimated when $I^2 > 50\%$. Publication bias was assessed by and Egger's tests [27]. Statistical significance was determined using two-sided tests, with a significance level set at $p < 0.05$. The standardized effect size (ES) was categorized according to Hopkins' guidelines: trivial (0.0–0.19), small (0.2–0.59), moderate (0.6–1.19), large (1.2–2.0), and very large (>2.0) [28]. If substantial heterogeneity was detected, sensitivity analyses were performed to assess the robustness of the results, and funnel plot analyses were conducted to investigate the presence of publication bias. In addition, subgroup analyses were conducted to determine the potential moderating factors that may affect the effectiveness of CNT intervention.

Subgroup analysis was performed based on population characteristics and training methods using dichotomous variables (female vs. male; amateur vs. elite) and continuous variables (age: <18 years or ≥ 18 years; training intensity: $\geq 85\%$ 1RM or $<85\%$ 1RM; frequency: $<3 \text{ week}^{-1}$ or $\geq 3 \text{ week}^{-1}$; duration: >6 weeks or ≤ 6 weeks) that might influence the outcomes following CNT and other interventions. Additionally, subgroup analyses were conducted for the primary sports (basketball, soccer, or handball) and the methods of COD measures (turn: ≤ 3 or >3). The cutoff was determined empirically based on prior literature [29–31]. The COD measurement methods were divided into two categories based on the number of turns: ≤ 3 turns (e.g., Shuttle Test, 505 Test, Arrowhead Test) and >3 turns (e.g., T-Test, Illinois Test, $S4 \times 5$ Test). To address the issue of intensity, when two different intensities were employed in a training intervention, the mean value was calculated for the subgroup analysis. For training frequency, studies were categorized into two groups based on the weekly training frequency: low frequency (<3 times per week) and high frequency (≥ 3 times per week). Two authors independently processed all data, with one responsible for extraction and the other for verification.

2.6. Study Quality Assessment

The quality of each included study was assessed using the National Institutes of Health's Quality Assessment Tool for Controlled Intervention Studies. This tool evaluates studies according to 14 criteria, assigning a score of 1 for a "yes" response and 0 for any other response. The study-specific global score, ranging from 0 to 14, was obtained by summing the scores across all criteria. This quality assessment served to measure the strength of scientific evidence but was not utilized to determine study inclusion.

3. Results

3.1. Study Selection

A comprehensive keyword search of various databases yielded 707 studies from various databases: 276 from PubMed, 136 from Web of Science, 88 from SPORTDiscus, 96 from Scopus, 23 from CINAHL, 49 from Academic Search Complete, 39 from Google Scholar, and 5 from forward and backward citation searches. Following the removal of duplicates, 413 unique studies were subjected to title and abstract screening, resulting in the exclusion of 372 studies. The full texts of the remaining 45 studies were reviewed against the study selection criteria. Of these, 20 studies were excluded. Reasons for exclusion

included the following: thirteen articles did not utilize CNT intervention [32–44], the full text of one study was not found [45], one study was not a chronic intervention study [46], two studies did not involve team sports [47,48], and two studies did not include a positive control group [49,50]. In total, twenty-five studies met the selection criteria and were included in the meta-analysis (Figure 1).

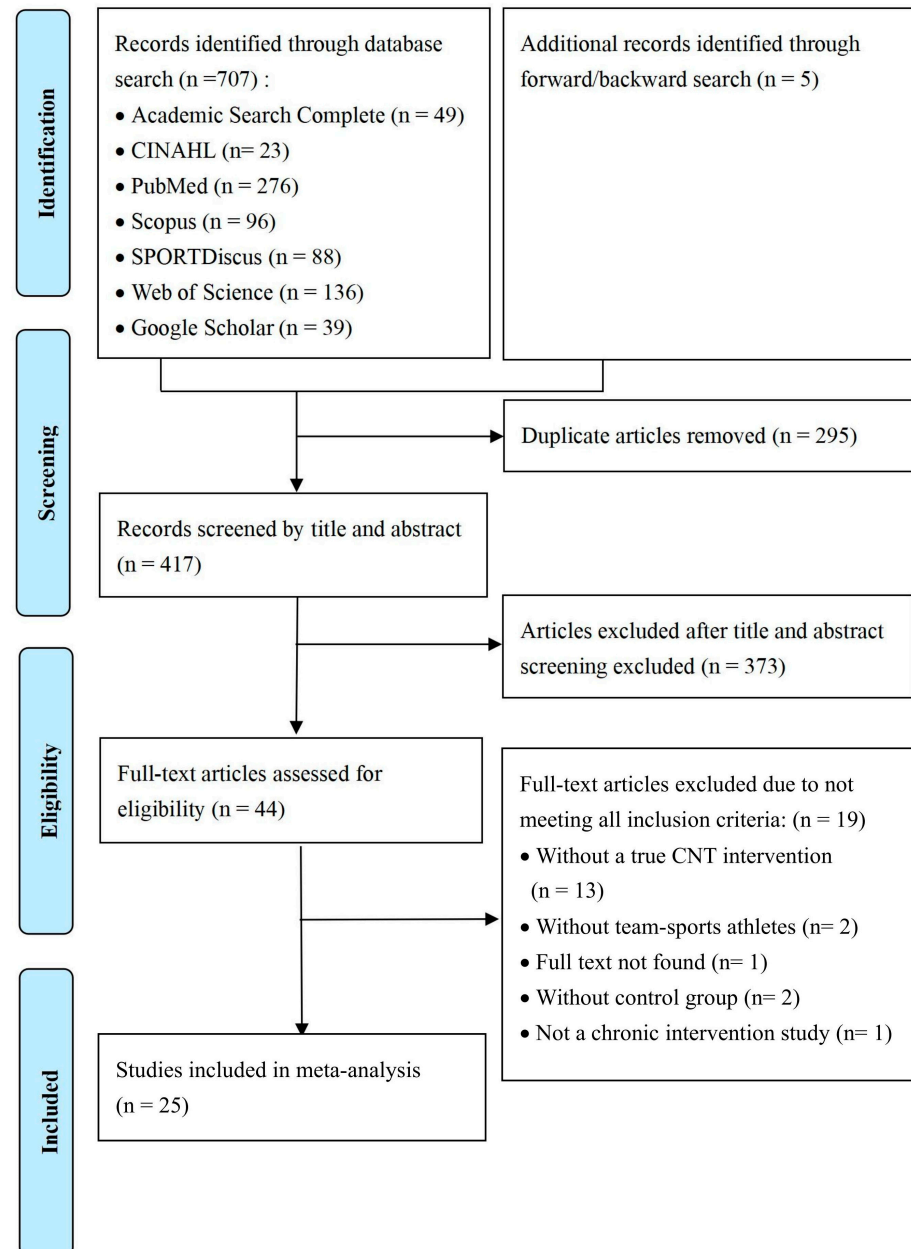


Figure 1. Flow diagram.

3.2. Basic Characteristics of the Included Studies

Table 1 summarizes the basic characteristics of the twenty-five studies included in the review. Among them, twenty-one were RCTs [6–9,13–15,51–61], and the remaining four were non-randomized field experiments [10,16,23,24]. Sample sizes were generally small, ranging from 14 to 91, with a mean of 28. Twelve studies exclusively examined adolescent athletes within the age range of 14 to 17 years, while another set of thirteen studies focused on young adults aged 18 to 25 years. Twenty-two studies recruited males, while three recruited females [6,53,62]. Eight studies recruited elite players, with five focusing on soccer, two on futsal [10,23], and one on basketball [54], while the remaining

seventeen recruited amateur players, including nine studies on soccer, three on basketball [6,9,24], and three on handball [8,53,62], along with one each on baseball [13], and one on hockey [15]. Regarding the CNT interventions, eleven studies adopted a combination of strength and plyometric training, nine studies incorporated strength, plyometric, and sprint training [51,63], and the remaining few focused on strength training paired with other forms of explosive exercises, such as sprint [10,58], optimal load training [54], and Olympic lifting-style exercises [22]. Additionally, one study used CNT combined with core training [23]. The intensity of lower-body strength training ranged from 50% to 100% one-repetition maximum (1RM), with several studies not reporting the specific intensity [23,62] and one study using bodyweight as the load intensity [57]. Intervention duration ranged from four to twelve weeks, with a weekly frequency of one to three sessions. Regarding the COD performance measures, the main measures utilized included the T-Test, the 505Test, the Illinois test, the Arrowhead test, the Sshuttle run, and agility with the ball tests.

Table 1. Basic characteristics of subjects, CNT interventions, and COD measures of the included studies.

Study ID	Group	N	Age	Gender	Sport/Level	CNT Interventions	COD Measures
Villanueva-Guerrero, 2024 [23]	CNT	14	17	M	Futsal/E	ST + PT + CST; 1 session; 8 week	V-Cut test
	CON	14					
Bin Wang, 2024 [6]	CNT	16	20	F	Basketball/A	ST + PT; 70–100% 1RM; 2–3 sessions; 8 weeks	505 Test; Illinois test
	ST	16					
Barra-Moura, 2024 [60]	CNT1	6	15	M	Soccer/A	ST + Sprint + PT; 80–90% 1RM; 2/3 sessions; 6 weeks	505 Test
	CNT2	7					
	CON	8					
Thapa, 2023 (A) [61]	CNT	8	20	M	Soccer/A	ST + PT; 65–85% 1RM; 2 sessions; 6 weeks	Modified T-Test
	CON	8	21				
Thapa, 2023 (B) [15]	CNT	8	21	M	Hockey/A	ST + PT; 65–85% 1RM; 3 sessions; 6 weeks	Modified T-Test
	CON	6	22				
Piotr Biel, 2023 [9]	CNT	13	24	M	Basketball/A	ST + PT; 80–85% 1RM; 2 sessions; 8 weeks	Shuttle Test
	AT	11	21				
Paul, 2023 [10]	CNT	9	20	M	Futsal/E	ST + Sprint; 60% 1RM; 2 sessions; 8 weeks	Illinois test
	DT	9					
Hammami, 2022 [62]	CNT	19	16	F	Handball/A	ST + PT; 2 sessions; 10 weeks	Modified Illinois test
	CON	19					
Erol, 2022 [63]	CNT	13	23	M	Soccer/A	ST + Sprint + PT; 70–85% 1RM; 3 sessions; 8 weeks	T-Test
	DT	10	21				
Gee, 2021 [22]	CNT	9	17	M	Soccer/E	ST + PT/OLS; 85% 1RM; 2 sessions; 10 weeks	Arrowhead test
	AT	8					
Hammami, 2019 [51]	CNT	14	16	M	Soccer/A	ST + PT + Sprint; 70–90% 1RM; 2 sessions; 8 weeks	S4 × 5 Test
	PT	14					
	CON	12					
Ali, 2019 [52]	CNT	12	22	M	Soccer/A	ST + PT; 80% 1RM; 3 sessions; 6 weeks	T-Test
	DT	12					
	CON	12					

Table 1. Cont.

Study ID	Group	N	Age	Gender	Sport/Level	CNT Interventions	COD Measures
Hammami, 2018 [53]	CNT CON	14 14	17	F	Handball/A	ST + PT + Sprint; 75–90% 1RM; 2 sessions; 10 weeks	Modified T-Test; Modified Illinois test
Spinetti, 2018 [7]	CNT ST	10 12	18	M	Soccer/E	ST + PT + Sprint; 90% 1RM; 3 sessions; 8 weeks	Zigzag pattern test
Freitas, 2018 [54]	CNT ST	9 9	21	M	Basketball/E	ST + OLT; 80% 1RM; 2 sessions; 6 weeks	T-Test
Nikolic, 2017 [24]	CNT CON	16 15	17– 18	M	Basketball/A	ST + PT; 60–80% 1RM; 2 sessions; 12 weeks	10 × 5 m Shuttle test
Kobal, 2017 [14]	CNT DT AT	9 9 9	19	M	Soccer/E	ST + PT; 60–80% 1RM; 2 sessions; 8 weeks	505 Test
Hammami, 2017 (A) [56]	CNT ST CON	16 16 12	16	M	Soccer/A	ST + PT + Sprint; 70–90% 1RM; 2 sessions; 8 weeks	S4 × 5 Test; Shuttle run S180°; Shuttle run SBF
Hammami, 2017 (B) [55]	CNT CON	17 12	17	M	Soccer/A	ST + PT + Sprint; 70–90% 1RM; 2 sessions; 8 weeks	S4 × 5 Test; Shuttle run S180°; Shuttle run SBF
Parrow, 2016 [8]	CNT ST PT	10 10 10	17	M	Handball/A	ST + PT; 50–60% 1RM; 3 sessions; 4 weeks	T-Test
Cavaco, 2014 [58]	CNT1 CNT2 CON	5 5 6	14	M	Soccer/A	ST + Sprint; 85% 1RM; 1/2 sessions; 6 weeks	Agility with the ball
García-Pinillos, 2014 [57]	CNT CON	17 13	16	M	Soccer/A	ST + PT; body weight; 2 sessions; 12 weeks	Balsom agility test
Faude, 2013 [59]	CNT CON	8 8	23	M	Soccer/E	ST + PT + Sprint; 50–60% 1RM; 2 sessions; 7 weeks	shuttle sprint and dribble test
Alves, 2010 [16]	CNT1 CNT2 CON	9 8 6	17	M	Soccer/E	ST + PT + Sprint; 80–90% 1RM; 1/2 sessions; 6 weeks	505 Test
Dodd, 2007 [13]	CNT PT ST	32 28 31	18–23	M	Baseball/A	ST + PT; 80–90% 1RM; 2 sessions; 4 weeks	T-Test

CNT, complex contrast training; CON, control group; AT, complex ascending training; PT, plyometric training; ST, strength training; DT, complex descending training; COD, change of direction; CST, core strength training; 1RM, 1 repetition maximum; OLS, Olympic lifting-style exercises; OLT, Optimal load training; M, male; F, female; A, amateur; E, elite.

3.3. Results of Meta-Analysis

Table 2 and Figure 2 represent the results of the meta-analysis. The analysis included five studies comparing the COD performance of CNT and a control group, three studies comparing CNT and PT, six studies comparing CNT and ST, four studies comparing CNT and DT, and three studies comparing CNT and AT. Results indicated that the improvement in COD performance from CNT and DT was similar ($ES = -0.08$; 95% $CI = -0.56, 0.39$; $I^2 = 0.0\%$; $\tau^2 = 0.000$), and the improvement from CNT and AT was also similar ($ES = 0.19$; 95% $CI = -0.28, 0.66$; $I^2 = 0.0\%$; $\tau^2 = 0.000$). On the other hand, compared to PT, ST,

and the control group, CNT led to a more substantial improvement in COD performance. Specifically, the ES of CNT compared to PT was 0.65 (95% CI = 0.18, 1.12; $I^2 = 0\%$; $\tau^2 = 0.000$), indicating a moderate improvement; the ES compared to ST was 0.88 (95% CI = 0.41, 1.36; $I^2 = 63.0\%$; $\tau^2 = 0.3229$), suggesting a moderate improvement as well; and the ES compared to the control group was 1.24 (95% CI = 0.88, 1.61; $I^2 = 65.1\%$; $\tau^2 = 0.4993$), representing a large improvement. No publication bias was identified based on Egger's test ($p > 0.05$). The funnel plot for the CNT comparison is provided in the Supplementary Materials.

Table 2. Results from meta-analysis and publication bias tests.

Intervention	No.	Hedges' g (95% CI)	Interpret	I^2	τ^2	Effect Model	Egger's Test (p)
CNT vs. CON	15	1.24 (0.88, 1.61)	Large	65.1%	0.4993	RE	0.377
CNT vs. ST	6	0.88 (0.41, 1.36)	Moderate	63.0%	0.3229	RE	0.215
CNT vs. PT	3	0.65 (0.18, 1.12)	Moderate	0.0%	0.0000	FE	0.055
CNT vs. DT	4	−0.08 (−0.56, 0.39)	Trivial	0.0%	0.0000	FE	0.663
CNT vs. AT	3	0.19 (−0.28, 0.66)	Trivial	0.0%	0.0000	FE	0.421

CNT, complex contrast training; CON, control group; PT, plyometric training; ST, strength training; DT, complex descending training; AT, complex ascending training; No., number of the included studies; Hedges' g, effect size; CI, confidence interval; I^2 , heterogeneity; τ^2 , tau squared; RE, random effect; FE, fixed-effect.

Table 3 represents the results of the subgroup analysis. CNT interventions showed a significantly greater effect in individuals under 18 years old, with ES of 1.13 (95% CI = 0.84, 1.42; $I^2 = 51.6\%$), compared to those 18 or older, who had an ES of 0.56 (95% CI = 0.19, 0.93; $I^2 = 65.8\%$). A similar trend was observed in female athletes, who exhibited a higher ES of 1.59 (95% CI = 0.82, 2.37; $I^2 = 76.8\%$) compared to males with an ES of 0.78 (95% CI = 0.54, 1.03; $I^2 = 58.0\%$). Similarly, amateur athletes responded better to CNT interventions, with an ES of 1.02 (95% CI = 0.75, 1.28; $I^2 = 68.4\%$), than elite athletes, who had an ES of 0.46 (95% CI = 0.00, 0.93; $I^2 = 61.0\%$). In terms of COD task measures, protocols with more than three direction changes (turn > 3) demonstrated a significantly greater effect, with an ES of 1.08 (95% CI = 0.75, 1.41; $I^2 = 72.5\%$), than those with three or fewer changes (turn ≤ 3), which had an ES of 0.51 (95% CI = 0.24, 0.78; $I^2 = 0.0\%$). Interestingly, no differential effect of CNT intervention was observed in COD performance enhancement among sport, intervention frequency, intervention intensity, and intervention duration covariates ($P_{\text{diff}} > 0.05$).

Subgroup analyses highlighted greater effects of CNT on COD performance in subjects under 18 years, female athletes, and amateur athletes. Specifically, participants under 18 showed an ES of 1.13, amateurs an ES of 1.02, and female athletes the highest ES of 1.59. However, the finding in female athletes is constrained by very limited data, as only three studies included female participants, necessitating cautious interpretation and highlighting the need for more research in this population.

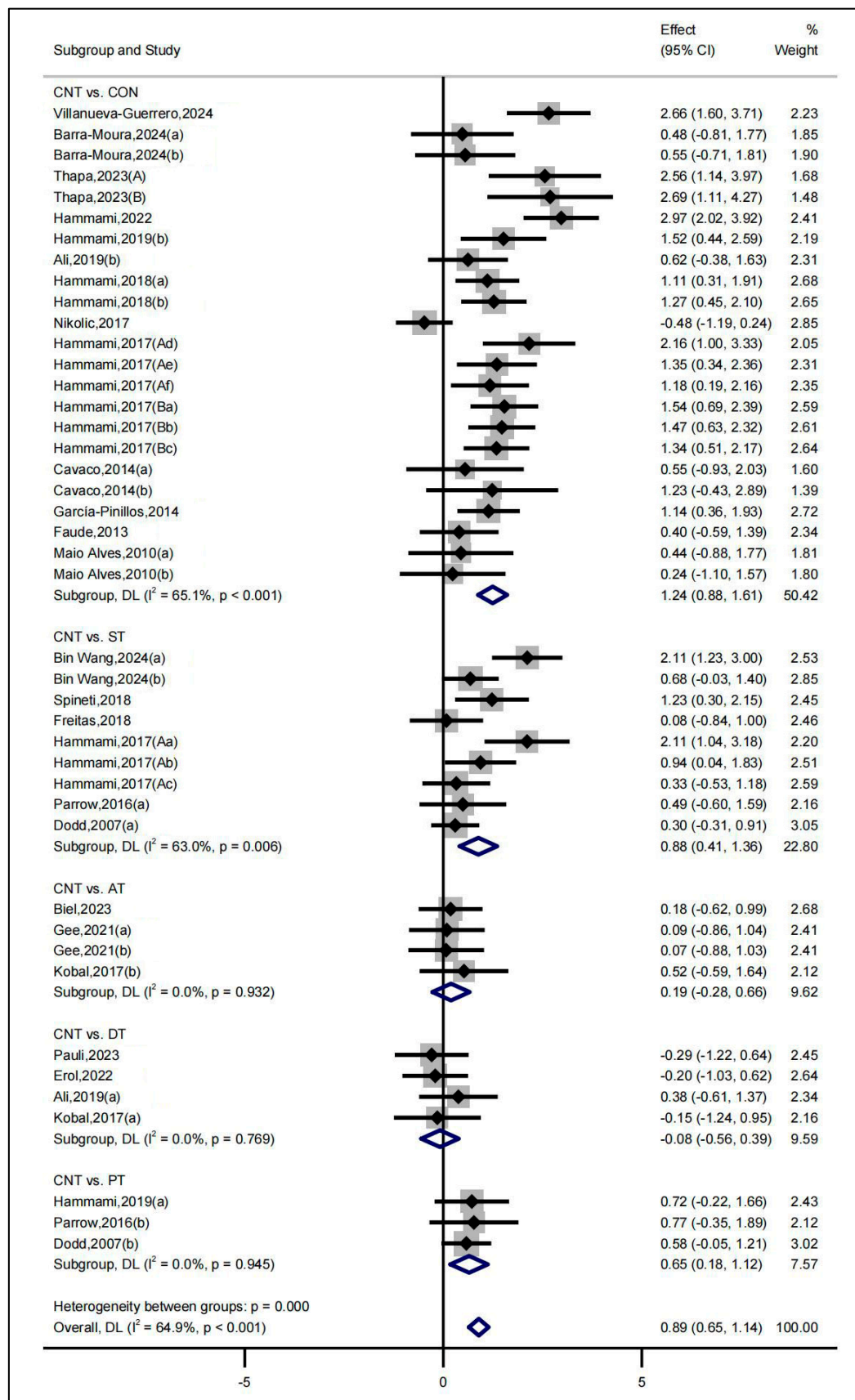


Figure 2. Forest plot. Results of a random-effect meta-analysis comparing CNT with other intervention protocols [6–10,13–16,22–24,51–63].

Table 3. Subgroup analysis assessing potential moderating factors for COD performance of CNT intervention.

Subgroup	No.	Hedges' g (95% CI)	I ² (%)	P _{diff}
Age (years)				
<18	12	1.13 (0.84, 1.42)	51.6	0.017 *
≥18	13	0.56 (0.19, 0.93)	65.8	
Gender				
Female	3	1.59 (0.82, 2.37)	76.8	0.049 *
Male	22	0.78 (0.54, 1.03)	58.0	
Sport				
Basketball	4	0.50 (−0.33, 1.33)	81.3	0.361
Soccer	14	0.87 (0.62, 1.13)	41.2	
Handball	3	1.34 (0.53, 2.16)	73.2	
Level				
Amateur	17	1.02 (0.75, 1.28)	68.4	0.044 *
Elite	8	0.46 (0.00, 0.93)	61.0	
Intervention				
Intensity				
<85% 1RM	18	1.00 (0.67, 1.32)	70.8	0.139
≥85% 1RM	7	0.65 (0.33, 0.98)	29.7	
Frequency				
<3 week ^{−1}	20	0.93 (0.65, 1.31)	67.9	0.415
≥3 week ^{−1}	6	0.69 (0.19, 1.19)	43.4	
Duration				
>6 weeks	16	0.98 (0.65, 1.31)	72.4	0.135
≤6 weeks	9	0.64 (0.33, 0.95)	19.9	
Measures				
Turn ≤ 3	9	0.51 (0.24, 0.78)	0.0	0.008 *
Turn > 3	17	1.08 (0.75, 1.41)	72.5	

COD, change of direction; No., number of the included studies; CI, confidence interval; I², heterogeneity; Hedges' g, effect sizes; P_{diff}, test for subgroup differences; *, statistical significance.

3.4. Results of Study Quality Assessment

Table A1 reports criterion-specific and global ratings from the study quality assessment. The included studies were assessed using the National Institutes of Health's Quality Assessment Tool for Controlled Intervention Studies, which includes 14 criteria. On average, the studies scored 10 out of 14, with scores ranging from 8 to 12, indicating moderate to high methodological quality. All studies strictly adhered to the pre-specified intervention protocols, addressed confounders by controlling baseline characteristics, and maintained consistent training plans with controlled intensity and volume. Additionally, outcomes were assessed using valid and reliable measures, and no additional training was arranged outside the study protocols. Twenty-one out of twenty-five studies used an adequate RCT design, while the remaining four were non-randomized field experiments. The overall dropout rate was within an acceptable range in most studies, with some exceptions. For instance, in some studies, the overall dropout rate at endpoint exceeded 20% of the number allocated to treatment, and the differential dropout rate between treatment groups also varied. Only one did not analyze the results based on its original random treatment allocation. Out of all the studies, only one utilized assessor blinding, and while all lacked double-blinding, some employed single-blinding of the subjects. The lack of double-blinding may introduce potential bias, although the use of single-blinding and rigorous adherence to intervention protocols helped mitigate this risk.

4. Discussion

We conducted a systematic review and meta-analysis regarding the effectiveness of CNT intervention on COD performance in team-sport athletes. We identified a total of

twenty-five studies from the keyword and reference search. Compared to PT, ST, and the control, CNT intervention was more effective in improving COD performance; however, CNT was not found to outperform DT and AT. The potentially beneficial effects derived from CNT seem particularly applicable to younger athletes (<18 vs. ≥ 18 years), female athletes (female vs. male), less skilled athletes (amateur vs. elite), and those who perform more COD turns (turn < 3 vs. turn ≥ 3). Moreover, in the studies included, no injuries related to CNT were reported. Overall, CNT appears to be a safe and effective training method compared to routine training alone.

The superior effectiveness of CNT over PT and ST can be attributed to its unique combination of heavy-load strength exercises and lighter-load power exercises performed in a set-for-set manner. This approach leverages the post-activation potentiation (PAP) phenomenon, where the performance of a high-intensity strength exercise (e.g., back squats) enhances the subsequent explosive power exercise (e.g., countermovement jumps) [18,19]. PAP is believed to increase the rate of force development (RFD) and maximal power output by enhancing neural drive and motor unit recruitment [64,65]. This mechanism is particularly beneficial for COD performance, which requires rapid deceleration, re-acceleration, and directional changes, all of which depend on the athlete's ability to generate force quickly and efficiently.

The adaptations resulting from CNT may stem from its ability to target both ends of the force–velocity spectrum: high-load, low-velocity exercises for strength and low-load, high-velocity exercises for power [11]. By integrating these two types of training, CNT optimizes the force–velocity profile, leading to greater improvements in COD performance compared to methods that focus on only one component [17,31]. This principle of combining strength and power training is also shared by DT and AT, which may explain why no significant differences were observed between these methods in improving COD performance. While CNT alternates between heavy-load and light-load exercises within the same set, DT adopts a sequential approach, completing all heavy-load exercises before moving on to light-load exercises [14,66,67]. In contrast, AT combines strength and power exercises by starting with light-load exercises followed by heavy-load exercises [22]. However, these minor differences in exercise sequencing and organization do not appear to produce significantly different outcomes in COD performance when the overall training volume and intensity are comparable [10,14].

The subgroup analyses revealed several factors that may influence the effectiveness of CNT on COD performance. Younger athletes (<18 years) exhibited a greater improvement in COD performance compared to older athletes (≥ 18 years), with ES of 1.13 and 0.56, respectively. This difference may be attributed to the greater plasticity of the neuromuscular system in younger individuals, which allows for more pronounced adaptations to training [60,68]. Adolescents are in a phase of rapid physiological growth, and their lower baseline levels of strength and power provide a higher potential for improvement [69]. CNT interventions may capitalize on this developmental window, leveraging the heightened adaptability of younger athletes to enhance COD performance more effectively [70].

Female athletes showed a larger effect size (ES = 1.59) compared to male athletes (ES = 0.78), indicating that CNT interventions may be particularly beneficial for female athletes. However, it is important to note that only three studies included female athletes, which makes generalizability limited. Despite this limitation, the observed difference may be related to the initial lower levels of strength and power in female athletes, providing more room for improvement [62,71]. Additionally, gender-specific biomechanics and neuromuscular adaptations, such as differences in muscle activation patterns and joint stability, may contribute to this greater potential for improvement [6]. Hormonal differences between sexes, particularly the lower levels of testosterone in females, may also result in

a greater relative response to training stimuli that enhance neuromuscular efficiency and power output [62].

Amateur athletes demonstrated greater improvements in COD performance compared to elite athletes. Elite athletes, who already possess high levels of strength and power, may have a smaller margin for improvement, making it more challenging to achieve significant gains in COD performance [54]. In contrast, amateur athletes, who typically have lower baseline levels of physical fitness, may experience more substantial improvements with CNT [61].

Despite the overall effectiveness of CNT in improving COD performance, our results showed no significant differences in the effects of CNT interventions across various sports, intervention frequencies, intensities, and durations ($P_{\text{diff}} > 0.05$). This finding suggests that the benefits of CNT in enhancing COD performance may be consistent across these variables, at least within the range examined in this meta-analysis.

However, it is important to note that the effects of CNT were more pronounced under certain specific training parameters. Specifically, when the training frequency was less than three sessions per week, the training intensity was below 85% 1RM, and when the training duration exceeded 6 weeks, the effects of CNT were more prominent. This finding is consistent with the results of Freitas' study [19], which demonstrated that CNT produced larger effect sizes under similar training conditions for sprint performance in team sports. This suggests that while the effectiveness of CNT may not be entirely dependent on specific training variables such as frequency, intensity, and duration, its effects may be more substantial within certain parameter ranges, even if these differences do not reach statistical significance. Our results indicate that CNT may be effective across varying levels of frequency, intensity, and duration, provided that the core principles of combining heavy-load strength exercises with lighter-load power exercises are maintained. However, this does not imply that optimal training parameters do not exist.

Tests involving more than three direction changes (turn > 3) showed a higher effect size ($ES = 1.08$) compared to those with fewer changes (turn ≤ 3 , $ES = 0.51$). This indicates that CNT interventions are particularly effective for complex COD tasks, which require greater neuromuscular control and coordination [31]. The repeated deceleration and re-acceleration in tasks with multiple turns may benefit more from the enhanced rate of force development (RFD) and power output induced by CNT, as these adaptations are critical for rapid changes in direction and efficient force generation [31]. In contrast, COD tasks with fewer turns may be more related to linear sprinting ability, which relies less on the rapid force production and neuromuscular coordination targeted by CNT [3,72].

Despite the robust findings, several limitations should be acknowledged. First, the included studies had varying sample sizes, and the majority were small-scale. This not only limits the generalizability of the results but also results in wide confidence intervals for some effect sizes, which may affect the precision of our estimates. Future research should aim to address these limitations by employing larger sample sizes to enhance the reliability and generalizability of the findings. Second, the lack of double-blinding in the studies may introduce bias, although this is a common challenge in exercise intervention studies. Third, the research on female athletes is limited in this area, which may restrict the generalizability of the findings to female players. Future research should explore these factors in more detail to identify optimal training protocols for different sports and populations.

5. Conclusions

This meta-analysis concludes that CNT is a highly effective method for improving COD performance, yielding superior results compared to standalone strength or plyometric training programs. However, its effectiveness is comparable to other combined training models like DT and AT. This suggests the primary driver of adaptation is the integration of

both high-load strength and high-velocity power exercises within the same program, with the specific sequencing of those exercises being of lesser importance.

The benefits of CNT are most pronounced in specific populations and contexts. The greatest performance gains were observed in younger athletes (<18 years), amateurs, and female athletes, who appear to have a greater capacity for neuromuscular adaptation to this training stimulus. Furthermore, CNT is particularly effective for enhancing performance in more complex agility patterns that require over three direction changes (e.g., T-Test, Illinois Test), making it highly relevant for sports like basketball, soccer, and handball.

Based on these findings, practitioners are encouraged to implement CNT as a safe and potent strategy to optimize COD ability. For practical application, programs lasting longer than six weeks, with a frequency of two sessions per week and a strength intensity below 85% 1RM, serve as an evidence-based starting point. This approach is especially recommended for developing youth, amateur, and female athletes, though future large-scale research is needed to further refine protocols for diverse populations.

Future research should aim to conduct larger-scale RCTs to confirm these findings and address current limitations, such as the scarcity of research involving female athletes and the lack of double-blinding in existing studies. Further exploration of these factors will help identify optimal training protocols for diverse sports and populations.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/app15137385/s1>. Figure S1: Forest plot. Results of a random-effect meta-analysis comparing CNT with other intervention protocols in different age subgroups; Figure S2: Forest plot. Results of a random-effect meta-analysis in different gender subgroups; Figure S3: Forest plot. Results of a random-effect meta-analysis in different level subgroups; Figure S4: Forest plot. Results of a random-effect meta-analysis in different COD measures; Figure S5: Funnel plots for CNT vs. CON; Figure S6: Funnel plots for CNT vs. PT; Figure S7: Funnel plots for CNT vs. ST; Figure S8: Funnel plots for CNT vs. DT; Figure S9: Funnel plots for CNT vs. AT.

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Abbreviations

The following abbreviations are used in this manuscript:

COD	Change of direction
CNT	Complex contrast training
ST	Strength training
PT	Plyometric training
DT	Complex descending training
AT	Complex ascending training
PAP	Post-activation potentiation

Appendix A

Table A1. Study quality assessment.

Criteria	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Was the study described as randomized, a randomized trial, a randomized clinical trial, or an RCT?	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1
Was the method of randomization adequate (i.e., use of randomly generated assignment)?	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1
Was the treatment allocation concealed (so that assignments could not be predicted)?	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1
Were study participants and providers blinded to treatment group assignment?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Were the people assessing the outcomes blinded to the participants' group assignments?	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Were the groups similar at baseline on important characteristics that could affect outcomes (e.g., demographics, risk factors, co-morbid conditions)?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Was the overall drop-out rate from the study at endpoint 20% or lower of the number allocated to treatment?	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	0	1	0
Was the differential drop-out rate (between treatment groups) at endpoint 15 percentage points or lower?	1	1	1	1	1	0	1	1	0	1	1	1	1	0	0	1	1	1	1	1	1	0	1	1	1
Was there high adherence to the intervention protocols for each treatment group?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Were other interventions avoided or similar in the groups (e.g., similar background treatments)?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Were outcomes assessed using valid and reliable measures, implemented consistently across all study participants?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Did the authors report that the sample size was sufficiently large to be able to detect a difference in the main outcome between groups with at least 80% power?	0	1	0	1	1	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
Were outcomes reported or subgroups analyzed pre-specified (i.e., identified before analyses were conducted)?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Were all randomized participants analyzed in the group to which they were originally assigned, i.e., did they use an intention-to-treat analysis?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Total	10	12	11	12	12	12	8	11	9	11	11	12	11	10	9	8	11	11	11	11	11	10	10	8	10

1 denotes yes and 0 denotes no.

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