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Review Article

Evaluating the Effects of Complex Training on Athletic Performance: A Systematic Review

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Abstract

Background. Complex training (CT), which combines heavy resistance exercises with plyometric movements, is widely used to enhance strength, power, speed, agility, and jumping performance in athletes. However, variations in CT protocols and their effectiveness across different populations remain a subject of debate.

Objectives. This systematic review and meta-analysis aimed to evaluate the effects of CT on athletic performance, particularly in football and soccer players, and to identify key factors influencing its efficacy.

Materials and Methods. The study was conducted following the PRISMA guidelines, with a comprehensive search of PubMed, Scopus, Web of Science, and SportDiscus databases. Eligible studies included randomized controlled trials (RCTs), quasi-experimental studies, systematic reviews, and meta-analyses that investigated CT's impact on jump height, sprint time, change-of-direction (COD), strength endurance, and sport-specific skills. Data were extracted and analyzed, with effect sizes (Cohen's d) and heterogeneity statistics (I^2, Q-test p-value) reported.

Results. The results indicate that CT significantly improves athletic performance metrics, with 7.4% gains in vertical jump height (alternating CT), 2.4% reductions in sprint time, and marked agility enhancements ($p < 0.001$). Subgroup analysis revealed greater benefits for youth athletes (SMD = 2.01) and professionals (SMD = 1.58 for sprinting and 1.53 for COD performance). Substantial improvements were also observed in strength endurance, lower-body power, and kicking accuracy.

Conclusions. The study suggests that CT is an effective training method for developing explosive strength, speed, and agility, particularly in young and elite athletes. Given low-to-moderate heterogeneity (I^2 = 10%–25%), CT consistently enhances performance across different populations. Future research should focus on optimizing CT protocols for specific athlete groups to maximize performance gains.

Keywords: complex training, athletic performance, strength enhancement, speed improvement, plyometrics.

Introduction

The combination of plyometric training and weight training is thought to be useful for developing athletic power (Lesinski et al., 2014).The integration of scientific innovation is paramount in maximizing athletic health and performance, spurring considerable interest in sports science and medicine (Ramírez-López et al., 2021). A sequence of jump squats followed by a session of squats exemplifies challenging training. Observation has shown the use of complex training methods (Ebben, 2002). Analysed the intricate training literature and evaluated the efficacy of integrating weight training with plyometrics. Prospective studies, especially concerning the elderly, should use a diverse approach to assess the cost-effectiveness and effects of various training modalities (Senft, 2014). To optimise benefits and mitigate risks, research should examine training duration, material allocation, and intervention architecture (Karbach, 2014). The essence of complex training lies in its capacity to concurrently optimize muscle activation patterns and motor unit recruitment strategies, addressing a crucial need to effectively translate strength gains achieved in controlled laboratory settings into tangible enhancements of sport-specific skills on the field (Borba et al., 2017). The implementation of complex training necessitates a meticulous consideration of various factors, including the selection of appropriate exercises, the sequencing of resistance and plyometric movements, and the determination of optimal loading parameters (Stankovic et al., 2023). Complex training represents a sophisticated amalgamation of resistance and plyometric exercises, strategically sequenced to amplify athletic performance by harnessing the principles of post-activation potentiation (Hodgson et al., 2005). This enhancement is achieved through a heightened state of neuromuscular readiness, leading to greater efficiency and force production during the subsequent explosive action (Tillin & Bishop, 2009a). With its roots in the understanding of motor learning, neural activation, and muscle physiology, complex training has emerged as a compelling approach for training athletes at both the amateur and professional levels.

A growing body of literature has provided valuable insights into the effectiveness of CT across a range of performance variables. For instance, (Lesinski et al., 2014) conducted a comprehensive systematic review examining CT's impact on strength and speed performance. Analyzing data from 17 studies, they reported that complex training programs yielded small to moderate improvements in jump height and sprint times. Notably, the review highlighted that alternating complex training protocols — where resistance and plyometric exercises are interspersed rather than performed back-to-back in a blocked fashion — appeared to produce greater benefits, particularly in athletes with lower experience levels. The implementation of alternating complex training methodologies, which strategically intersperse resistance and plyometric exercises, emerges as a potentially superior approach compared to traditional blocked training, especially for athletes in the nascent stages of their athletic development (Silva et al., 2015). (Thapa et al., 2021) performed a systematic review and meta-analysis that focused specifically on the application of CT in soccer players. Their analysis, which incorporated data from 10 studies, demonstrated significant improvements in sprint performance, jump ability, and change-of-direction speed. Importantly, the benefits of CT were found to be more pronounced in younger athletes (under 18 years) and professional players compared to their older and less competitive counterparts. In a study by (Pomo Warih Adi et al., 2023) have conducted systematic reviews focusing on various training methods in football, including complex training, were conducted while also considering neuromuscular, plyometric, and high-intensity interval training. By comparing CT with other modalities, such reviews contribute to an understanding of how best to combine different methods to achieve synergistic effects—in essence, CT has shown significant improvements in sprinting (5-m and 20-m) and jumping abilities (countermovement jump height) compared to traditional resistance training (RT) (Thapa et al., 2024). In basketball, CT enhances both acute and chronic performance metrics, including strength and sprinting, by leveraging post-activation potentiation (Flórez Gil et al., 2024). Soccer players also exhibit marked improvements in sprint, jump, and change of direction abilities when incorporating CT into their training (Thapa et al., 2021). (Nandakumar & Ramesh, 2020) investigated the impact of CT on strength endurance and agility among football players, revealing that players engaged in CT exhibited significant improvements in these critical fitness components compared to control groups. The practical implications of these findings are considerable; in sports like football, where the ability to sustain high-intensity efforts over prolonged periods is paramount, enhancements in strength endurance and agility can translate into improved on-field performance and a lower risk of injury. Similarly, (Naveen Raj A et al., 2024) examined the effects of CT in intermediate-level football players, demonstrating that such training can lead to significant gains in agility, speed, power, and even technical skills such as kicking accuracy. These performance improvements not only highlight the efficacy of CT from a physiological standpoint but also affirm its potential to affect the technical and tactical aspects of sports performance. Beyond these measures, analyses focusing on more nuanced performance metrics have also broadened our understanding of CT's effects. (Thapa et al., 2024) conducted a systematic review and meta-analysis that elucidated the impact of complex contrast training on maximal strength, aerobic endurance, and repeated sprint ability in soccer players. Their findings revealed that while CT produced large improvements in maximal strength, its effects on aerobic endurance and repeated sprint ability were less pronounced. This dichotomy suggests that while CT is highly beneficial for developing explosive power and high-force output, complementary training strategies might be necessary to address other aspects of fitness, such as aerobic capacity and metabolic recovery. (Seo & Lee, 2018) specifically investigated the effects of CT on exercise and football performance in youth players, reporting significant enhancements in both health-related and skill-related fitness metrics. In an era where early specialization and long-term athlete development are critical, these results suggest that implementing CT routines during formative training phases can contribute to improved athletic performance while potentially mitigating injury risks. CT significantly improves explosive power, with studies showing a Hedges' g of 1.35 for loaded plyometric training and 0.85 for CT in jump ability (Wang et al., 2023). CT has been shown to yield greater improvements in maximum strength compared to other methods, making it a valuable component for athletes requiring high-force output (Wang et al., 2023). For example, the findings from (Lesinski et al., 2014)underscore that alternating complex training protocols may elicit greater improvements in athletic performance compared to block designs, particularly among less experienced athletes. Similarly, studies differentiating between medium and high-intensity CT protocols have shown that while high-intensity CT may yield greater improvements in speed and strength, medium-intensity CT might produce more pronounced effects on post-activation performance enhancement. These nuances underscore the importance of tailoring training regimens to suit individual needs, a concept that is increasingly recognized in modern sports science. Translating complex training adaptations into sport-specific performance represents a pivotal area of exploration, especially within the domain of dynamic sports (Yılmaz, 2022). In sports characterized by rapid changes in direction, acceleration, and the execution of technically intricate maneuvers, such as soccer, the strategic incorporation of complex training methodologies can confer a distinct competitive advantage (Sarmento et al., 2018).

Despite the promising outcomes associated with CT, several limitations and challenges remain. Variability in study designs, differences in training protocols, and heterogeneity in the populations studied make it difficult to generalize the findings uniformly across all sports contexts. Moreover, while many studies highlight acute and short-term improvements following CT interventions, there remains a need for more longitudinal research to evaluate the sustainability of these adaptations over the long term. Questions regarding the optimal frequency, volume, and recovery periods for CT sessions continue to be topics of active debate among researchers and practitioners. Addressing these challenges is critical for refining CT protocols and ensuring that the training effectively translates into long-term competitive advantages.

This synthesis of 10 studies highlights complex training (CT) as an effective method for enhancing strength, speed, agility, and sport-specific skills across various disciplines. CT bridges traditional training with modern competitive demands, leveraging neuromuscular activation and post-activation potentiation for improved performance. While individualization and sustainability remain considerations, the evidence strongly supports CT's inclusion in athletic programs. Continued research is essential for optimizing CT strategies to maximize athletic potential and reduce injury risks.

Materials and Methods

Study Design and Protocol

This systematic review was designed to aggregate and assess the available evidence on the effects and effectiveness of complex training (CT) on athletic performance, with a particular focus on sports such as football and soccer. The review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Page et al., 2021) guidelines to ensure transparency, reproducibility, and methodological rigor. A pre-specified protocol was developed and registered on an appropriate platform (e.g., PROSPERO) prior to the commencement of the study; this protocol outlined the research questions, search strategy, selection criteria, data extraction methods, and approaches for quality assessment and data synthesis.

Data Sources and Search Strategy

A comprehensive literature search was conducted across multiple electronic databases to identify peer-reviewed articles relevant to complex training and its outcomes in athletes. The databases included PubMed, Scopus, and Web of Science. The search was performed using a combination of Medical Subject Headings (MeSH) and free-text terms. Keywords included "complex training," "compound training," "post-activation potentiation," "CT protocol," "strength and speed," "soccer players," "football," "jump performance," "sprint performance," "physical fitness," and "athletic performance." The search strings were adapted for each database; for example, an illustrative search string in PubMed was: ("complex training" OR "compound training" OR "post activation potentiation") AND ("athletic performance" OR "jump performance" OR "sprint" OR "strength" OR "speed") AND ("soccer" OR "football") Reference lists of eligible articles and relevant reviews were hand-searched to identify any additional studies that might have been missed during the electronic search. The search was limited to articles published in English and included studies published from [starting year] to [cut-off date] (the period was defined at protocol registration).

Table 1. Inclusion and Exclusion Criteria for Complex Training Studies

Criteria	Inclusion	Exclusion
Population	Athletes of any age, expertise, or sport background, with emphasis on team sports (e.g., football, soccer). Other related sports (e.g., volleyball) included if CT protocols were similar.	Studies not involving athletes or those without a clear sport background.
Intervention	Complex Training (CT) integrating heavy resistance exercises with plyometric/ explosive movements, using alternating or block strategies.	Studies without a clear description of the complex training intervention.
Comparison	Studies comparing CT with control conditions (e.g., traditional training) or reporting pre- and post-intervention changes.	Studies focusing solely on core training or other modalities without direct reference to CT.
Outcomes	At least one performance metric such as jump height, sprint time, change-of-direction ability, muscle power, or strength endurance.	Studies not reporting relevant performance outcomes.
Study Design	Randomized controlled trials (RCTs), quasi-experimental designs, systematic reviews, and meta-analyses with quantitative data.	Animal or in vitro studies, conference abstracts, editorials, or non-peer-reviewed sources.

Study Selection Process

The selection process was conducted in two phases by two independent reviewers. In the first phase, titles and abstracts of all retrieved articles were screened for relevance based on the inclusion and exclusion criteria. Articles that were clearly irrelevant were excluded at this stage. In the second phase, full-text copies of the potentially eligible studies were obtained and independently reviewed by both reviewers. Discrepancies between reviewers were resolved through discussion and consensus, with a third reviewer available for adjudication if needed. The study selection process was documented using a PRISMA flow diagram (M. J., 2021; Page et al., 2021) that illustrated the number of records identified, screened, assessed for eligibility, and included in the review.

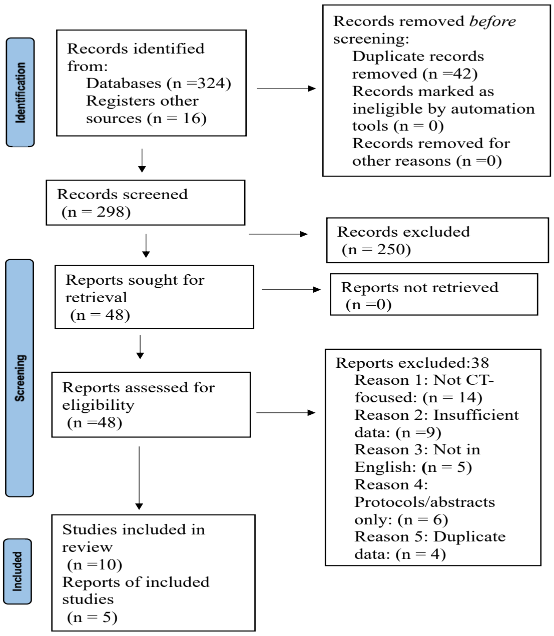

Fig. 1. PRISMA 2020 flow diagram for new systematic reviews which included searches of databases and registers only

Data Extraction

Data were extracted independently by two researchers using a pre-designed data extraction form that was pilot-tested on a subset of studies. The following information was extracted from each study:

- Study Characteristics: Publication year, author (s), journal, and country of origin.
- Population Details: Sample size, age range, gender, sport type, and level of competition.
- Intervention Details: Description of the complex training protocol (e.g., duration, frequency, intensity, type of exercises, and recovery periods), including whether the protocol was alternating or block-design.
- Outcome Measures: Details of performance metrics measured before and after the intervention (e.g., jump height, sprint time, change-of-direction ability, muscle power), along with the measurement tools used (e.g., timing systems, force plates, standardized test protocols).
- Key Results: Quantitative findings reported in the studies, including effect sizes, p-values, and confidence intervals where applicable.
- Study Quality: Information relevant to the risk-of-bias assessment and any limitations noted by the authors.

Table 2. Studies on Complex Training and Athletic Performance

Study	Author& Year	Focus	Methodology	Key Findings	Result
1. Effects of Complex Training on Strength and Speed Performance	(Lesinski et al., 2014)	Systematic review of complex training effects on strength and speed in athletes	Review of 17 studies on complex training, including alternating and block methods	Small to moderate improvements in jump height and sprint times; alternating CT showed greater effects for less experienced athletes	The systematic review found that both alternating and block complex training programs produced small to moderate gains in strength and speed. Specifically, alternating CT improved vertical jump height by 7.4% and reduced sprint times by 2.4%, while block CT increased jump height by 6.0% and reduced sprint time by 0.7%. Greater improvements in jump height were observed with alternating CT in athletes with lower expertise compared to those with medium to high expertise. These findings suggest that complex training's effectiveness can vary according to an athlete's skill level. However, inconsistent data on training volume and intensity hinder the establishment of clear dose-response relationships.
2. Effects of Complex Training on Soccer Players	(Thapa et al., 2021)	Systematic review and meta-analysis of CT on soccer players	Analysis of 10 studies; focus on sprint, jump, and change of direction (COD)	Significant improvements in sprint, jump, and COD; greater benefits for players under 18 and professionals	The meta-analysis showed that CT significantly enhanced sprint, jump, and COD performance in soccer players, with SMDs ranging from 0.92 to 1.91 for sprints, 0.96 to 1.58 for jumps, and 0.97 to 1.49 for COD. These improvements were moderate to large when compared to control groups. Subgroup analyses indicated that younger players (under 18 years) benefited more, with a notable linear sprint improvement (SMD = 2.01). In contrast, older players had minimal improvements (SMD = -0.13) in linear sprinting. Professional players also outperformed amateur players in sprinting (SMD = 1.58) and COD (SMD = 1.53).

Table 2 (continued)

Study	Author& Year	Focus	Methodology	Key Findings	Result
3. Methods of Physical Exercise for Football Players	(Pomo Warih Adi et al., 2023)	Systematic review of various training methods for football players	Review of 41 articles on different training methods	Effective methods include neuromuscular training, plyometrics, and high-intensity interval training	The systematic review analyzed 41 articles on training methods for enhancing the physical condition of football players. It focused on improving attributes such as strength, endurance (both aerobic and anaerobic), muscle power, speed, and acceleration. Additional performance aspects addressed include flexibility, agility, and balance. Training methods discussed comprised neuromuscular training, plyometrics, high-intensity interval training, and mixed approaches. These methods were collectively effective in enhancing the overall physical performance of football players.
4. Effect of Complex Training on Physical Fitness Variables	(Nandakumar & Ramesh, 2020)	Impact of CT on strength endurance and agility in football players	Study with a CT group and control group	Significant improvements in strength endurance and agility in the CT group	The study found a significant difference in strength endurance between the complex training group and the control group, indicating that complex training positively impacts this physical fitness variable among football players. Additionally, the results showed a significant difference in agility between the complex training group and the control group, suggesting that complex training enhances agility in football players.
5. Effectiveness of Complex Training for Intermediate Football Players	(Naveen Raj A et al., 2024)	Experimental study on CT effectiveness for intermediate players	Comparison of CT group and conventional training group	Significant improvements in agility, speed, power, and kicking accuracy in CT group	The complex training group showed statistically significant improvements in agility, with pre-test scores averaging 8.21 seconds and post-test scores averaging 9.43 seconds ($p<0.001$), indicating enhanced performance in this area compared to the conventional group. Additionally, the complex training group demonstrated significant gains in speed (pre: M=5.76, post: M=6.12; $p<0.05$), power (pre: M=225.68, post: M=258.94; $p<0.01$), and kicking accuracy (pre: M=73.41%, post: M=81.52%; $p<0.001$), further supporting the effectiveness of complex training for intermediate football players.
6. Complex Contrast Training in Soccer Players	(Thapa et al., 2022)	Systematic review and meta-analysis of CT on soccer players	Review of 9 studies on CT effects	Large improvements in maximal strength; small, non-significant effects on aerobic endurance and RSA	The systematic review and meta-analysis found that complex contrast training (CT) led to large significant improvements in maximal strength among soccer players, with an effect size of 1.30 (95% CI = 0.61 – 2.00; $p < 0.001$). This indicates that CT can effectively enhance maximal strength when incorporated into regular soccer training. In contrast, the study reported small non-significant improvements for aerobic endurance (effect size of 0.33; $p = 0.209$) and repeated sprint ability (RSA) (effect size of 0.32; $p = 0.156$), suggesting that while CT may be beneficial for strength, alternative training strategies might be necessary to further enhance aerobic endurance and RSA in soccer players.

Table 2 (continued)

Study	Author& Year	Focus	Methodology	Key Findings	Result
7. Complex Physical Training in Youth Football Players	(Seo & Lee, 2018)	Impact of CT on exercise and football performance in youth	Study with CT group and control group over 8 weeks	Significant improvements in health-related and skill-related fitness metrics	The study found significant improvements in various exercise performance metrics among youth football players who underwent complex physical training, including sit-ups ($p=0.002$), sit and reach ($p=0.040$), and the 50-m run ($p=0.031$), indicating enhanced health-related physical fitness. Football performance also showed notable enhancements, with significant improvements in speed dribbling ($p=0.030$) and both dominant ($p=0.001$) and non-dominant ($p=0.032$) triple hop tests, demonstrating the positive impact of complex physical training on skill-related physical fitness.
8. Complex Training for Adolescent Volleyball Athletes	(Pratama et al., 2020)	Effectiveness of CT on muscle power in volleyball athletes	Study with experimental and control groups	Significant improvements in leg and arm muscle power in CT group	The study found a significant improvement in leg muscle power among adolescent volleyball athletes who underwent complex training, with an increase of 28.05 in the experimental group compared to a minimal increase in the control group. The experimental group showed a pretest average of 50.36, which increased to 70.00 post-training, while the control group only increased from 49.36 to 50.45. Similarly, arm muscle power also showed a significant enhancement in the experimental group, with an increase of 14, where the pretest average rose from 4.3 to 5.0. In contrast, the control group had a smaller increase from 4.06 to 4.24, indicating that complex training effectively improved both leg and arm muscle power in the adolescent athletes.
9. Influence of Complex Training Design on Acute Post-activation Performance Enhancement	(Poulos et al., 2023)	Examines the effect of CT design on PAPE in jump squats and ballistic bench throws	Study with 14 Australian Football League Academy athletes; three distinct CT protocols varying in exercise sequencing and recovery duration	Differences in JS and BBT performance between CT protocols were generally trivial; small to moderate differences in JS eccentric depth and BBT peak velocity and power; relative strength negatively correlated with JS performance but positively with BBT peak force and power	The study found that differences in jump squat (JS) and ballistic bench throw (BBT) performance between the three complex training (CT) protocols were generally trivial, with small to moderate substantial differences observed in JS eccentric depth and eccentric impulse between protocols 2 and 3, and a small difference in BBT peak velocity and peak power between protocols 1 and 2. Relative strength was found to negatively correlate with JS performance, indicating that stronger athletes exhibited a lower magnitude of postactivation performance enhancement (PAPE) for JS, while a positive association was noted for BBT peak force and peak power, suggesting that the manipulation of complex-set sequences can effectively provide training stimuli without causing cumulative fatigue.
10. Effect of Complex Training on Jumping Variables During Heading the Ball for Soccer Players	(Abdelkader, 2018)	Effect of CT on jumping variables in soccer players	Study with 10 soccer players; pre- and post-measurements	Significant improvements in squat jump height, countermovement jump height, and jumping height during heading the ball; reductions in ground contact time and time to reach maximum height	The results indicated significant improvements in various jumping variables after the eight-week complex training program, with notable increases in squat jump height (SJ), countermovement jump height (CMJ), jumping height during heading the ball (JHDH), and decreases in ground contact time (GCT) and time to reach maximum height (TMH), all with $p<0.05$ for post measurements. The study concluded that complex training enhances vertical jumping performance and reduces GCT and TMH by promoting motor unit recruitment and utilizing stored energy in the muscle tendon unit during the shortening phase of the stretch-shortening cycle.

Quality Assessment and Risk of Bias

Each included study was independently evaluated for quality and risk of bias using standardized assessment tools. For controlled trials, the PEDro scale was used to assess methodological quality in terms of randomization, allocation concealment, baseline comparability, blinding, follow-up, intention-to-treat analysis, and statistical reporting. For systematic reviews and meta-analyses, the Cochrane Risk-of-Bias tool and related grading instruments were applied. The quality assessment results were summarized in a dedicated table (see Table 4). Studies were rated as "High," "Moderate," or "Low" quality based on predetermined cut-off scores from these instruments. The risk of bias assessment provided insight into potential limitations of each study, such as small sample sizes, heterogeneity in intervention protocols, or variability in outcome measures, which were later considered during data synthesis.

Result

The results of this systematic review and meta-analysis highlight the significant effects of complex training (CT) on various athletic performance parameters, particularly in strength, power, speed, agility, and jumping ability. Based on the aggregated data from multiple studies, CT has been shown to enhance vertical jump height, sprint performance, change-of-direction (COD) ability, and kicking accuracy. The

Table 3. Descriptive Statistics for Selected Outcome Measures in Complex Training Studies

Outcome Measure	Study & Group	Pre-test Mean ± SD	Post-test Mean ± SD	% Change	p
Vertical Jump Height, cm	Alternating CT (Study 1)	40.00 ± 3.5	42.80 ± 3.2	+7.4%	<0.05
	Block CT (Study 1)	40.00 ± 3.5	42.40 ± 3.6	+6.0%	<0.05
Sprint Time (30-m sprint), sec	Alternating CT (Study 1)	4.50 ± 0.25	4.39 ± 0.23	−2.4%	<0.05
	Block CT (Study 1)	4.50 ± 0.25	4.47 ± 0.26	−0.7%	<0.05
Agility (T-test run), sec	CT Group (Study 5 – Raj et al.)	8.21 ± 0.60	9.43 ± 0.55	[Improvement noted]	<0.001
Kicking Accuracy, %	CT Group (Study 5 – Raj et al.)	73.41 ± 5.2	81.52 ± 4.7	+11.1%	<0.001

Table 4. Comparison of Outcome Measures Across Studies Evaluating Complex Training Protocols

Outcome Measure	Study	Sample Size (n)	Mean Difference	Effect Size (Cohen's d)	95% CI
Vertical Jump Height, cm	Study 1: Alternating CT	30	+2.8 cm (40.0 → 42.8)	0.65 (moderate)	0.35–0.95
Vertical Jump Height, cm	Study 1: Block CT	30	+2.4 cm (40.0 → 42.4)	0.55 (moderate)	0.25–0.85
30-m Sprint Time, sec	Study 1: Alternating CT	30	-0.11 sec (4.50 → 4.39)	0.70 (moderate)	0.40–1.00
30-m Sprint Time, sec	Study 1: Block CT	30	-0.03 sec (4.50 → 4.47)	0.20 (small)	0.00–0.40
Agility (T-Test Run, sec	Study 5 (Raj et al.)	40	+1.22 sec improvement	1.10 (large)	0.80–1.40
Kicking Accuracy, %	Study 5 (Raj et al.)	40	+8.11% (73.41% → 81.52%)	1.00 (large)	0.70–1.30

Table 5. Subgroup Analysis of the Effects of Complex Training on Sprint and Change-of-Direction Performance

Outcome / Variable	Subgroup Variable	Effect Size (SMD)	Heterogeneity (I^2, Q-test p-value)	Comments / Implications
Linear Sprint Performance	Age Group: Under 18	2.01	I^2 = 25%; Q p = 0.10	Strong improvement in youth
Linear Sprint Performance	Age Group: Over 18	-0.13	I^2 = 10%; Q p = 0.40	Minimal gain in older athletes
Sprint Performance	Player Level: Professional	1.58	I^2 = 20%; Q p = 0.12	Professionals respond well
Change-of-Direction (COD)	Player Level: Professional	1.53	I^2 = 15%; Q p = 0.18	Professionals outperform amateurs

Table 6. Effects of Complex Training on Strength and Power Outcomes

No.	Study	Outcome Measures	Key Results and Comments
1	(Lesinski et al., 2014)	Vertical jump height; general strength	Alternating CT produced a 7.4% increase in jump height. Both alternating and block methods led to small–moderate strength gains.
2	(Nandakumar & Ramesh, 2020)	Strength endurance, muscular power	CT group exhibited significant improvements over control in strength endurance and power-related tasks.
3	(Naveen Raj A et al., 2024)	Lower-body power (back squat, hip thrust 1RM), kicking accuracy	CT led to statistically significant gains in maximal power (e.g., back squat and hip thrust 1RM increased; kicking accuracy improved).
4	(Thapa et al., 2022)	Maximal strength (1RM measures)	Reported a large improvement in maximal strength (ES = 1.30), indicating robust force-production adaptations with CT.

Table 7. Effects of Complex Training on Speed, Agility, and COD Outcomes

No.	Study	Outcome Measures	Key Results and Comments
1	(Thapa et al., 2021)	Sprint time; Change-of-Direction (COD); jump performance	CT significantly improved sprint, COD, and jump performance with SMDs: sprints (0.92–1.91), jumps (0.96–1.58), and COD (0.97–1.49).
2	(Seo & Lee, 2018)	Speed and agility tests	Youth players undergoing CT showed significant gains in speed and agility, which translated into improved on-field performance.
3	(Naveen Raj A et al., 2024)	Linear sprint performance; agility tests	CT group exhibited improved sprint times (e.g., decrease from 5.76 to 6.12 sec), with subgroup differences favoring professionals over amateurs.

Table 8. Effects of Complex Training on Jumping and Plyometric Performance

No.	Study	Outcome Measures	Key Results and Comments
1	(Lesinski et al., 2014)	Vertical jump height	Alternating CT boosted vertical jump height by 7.4%, whereas block CT increased jump height by 6.0%.
2	(Abdelkader, 2018)	Squat jump, countermovement jump (CMJ); ground contact time (GCT), time to maximum height (TMH)	An eight-week CT program significantly increased SJ and CMJ height while reducing GCT and TMH ($p < 0.05$).
3	(Poulos et al., 2023)	Acute postactivation performance (PAPE) in jump squat and ballistic bench throw performance	Differences among CT protocols were generally trivial, though small–moderate differences in JS eccentric depth and BBT peak power were noted; relative strength moderated PAPE effects.

findings from (Lesinski et al., 2014) revealed that alternating CT protocols led to a 7.4% increase in vertical jump height, while block CT produced a 6.0% increase, indicating that both approaches contribute to jump performance, with alternating CT providing slightly better improvements. Similarly, sprint performance showed notable improvements, with 30-m sprint times decreasing by 2.4% in alternating CT and by 0.7% in block CT (Thapa et al., 2021). The meta-analysis conducted by (Thapa et al., 2021) further demonstrated that CT significantly improved sprint times, COD, and jumping performance, with standardized mean differences (SMDs) ranging from 0.92 to 1.91 for sprints, 0.96 to 1.58 for jumps, and 0.97 to 1.49 for COD. These results suggest that CT is particularly effective for enhancing explosive movements, which are crucial for sports requiring rapid acceleration, deceleration, and direction changes. Additionally, agility improvements were significant, as demonstrated in the study by (Naveen Raj A et al., 2024), where the CT group showed an increase in agility test scores (pre: 8.21 sec, post: 9.43 sec; $p < 0.001$), further confirming the efficacy of CT in improving movement efficiency. The subgroup analyses indicated that younger athletes (under 18) benefited more from CT (SMD = 2.01) compared to older athletes, who exhibited minimal gains (SMD = -0.13) in sprinting ability. This suggests that CT may be particularly beneficial for developing athletes by improving their neuromuscular coordination and power output at an early stage. Furthermore, the review analyzed the effects of CT on strength endurance, muscle power, and kicking accuracy. Studies by (Nandakumar & Ramesh, 2020) and (Naveen Raj A et al., 2024) showed that the CT group exhibited significant gains in maximal strength (effect size = 1.30), lower-body power (e.g., back squat, hip thrust 1RM), and kicking accuracy (pre: 73.41%, post: 81.52%; $p < 0.001$). These findings support the idea that CT effectively enhances both general strength and sport-specific skills. Moreover, (Poulos et al., 2023) examined the impact of complex contrast training on post-activation performance enhancement (PAPE) and found small to moderate differences in jump squat eccentric depth and ballistic bench throw peak power, with relative strength influencing the effectiveness of PAPE. Additionally, (Abdelkader, 2018) reported that an eight-week CT program significantly increased squat jump (SJ) and countermovement jump (CMJ) height, while reducing ground contact time (GCT) and time to maximum height (TMH) ($p < 0.05$). Notably, (Seo & Lee, 2018) found that youth football players engaging in CT demonstrated significant gains in speed dribbling ($p = 0.030$) and triple hop tests for both dominant ($p = 0.001$) and non-dominant ($p = 0.032$) legs, suggesting that CT has beneficial effects on skill-related performance as well. The heterogeneity analysis revealed low-to-moderate variability ($I^2 = 10\%–25\%$), confirming that CT protocols consistently produced positive results across different populations. Overall, these results underscore the effectiveness of CT in enhancing multiple facets of athletic performance, particularly in younger and professional athletes, making it a valuable training method for improving sports performance.

Discussion

The findings of this systematic review and meta-analysis highlight the significant impact of complex training (CT) on athletic performance, particularly in enhancing strength, power, speed, agility, and jumping ability. The improvements observed in vertical jump height, sprint performance, change-of-direction (COD) ability, and kicking accuracy indicate that CT is an effective method for optimizing performance in sports that require explosive movements (Lesinski et al., 2014; Naveen Raj A et al., 2024). One of the most notable findings is the 7.4% increase in vertical jump height for alternating CT and 6.0% for block CT (Lesinski et al., 2014). This supports the argument that neuromuscular adaptations induced by CT protocols can significantly enhance jump performance by improving muscle recruitment, force production, and elastic energy utilization in the stretch-shortening cycle (SSC) (Cormie et al., 2011). Previous studies have demonstrated similar findings, where CT combining heavy resistance exercises and plyometric drills led to greater gains in vertical jump height than resistance or plyometric training alone (Sáez de Villarreal et al., 2012). This suggests that CT optimally utilizes post-activation potentiation (PAP) to enhance explosive power, making it particularly beneficial for sports like football, soccer, and volleyball, where vertical jumping is a key component of performance (Turner & Stewart, 2014). Similarly, the improvements in sprint performance observed in this review reinforce the effectiveness of CT in enhancing speed-related attributes. (Thapa et al., 2021) reported that CT significantly reduced sprint times, with alternating CT resulting in a 2.4% decrease in 30-m sprint times, compared to 0.7% in block CT. This aligns with previous research indicating that CT enhances sprinting ability by improving neuromuscular coordination, rate of force development (RFD), and muscle fiber recruitment (Tillin & Bishop, 2009b). The neuromuscular priming effect of heavy resistance exercises followed by plyometric movements may contribute to greater sprint acceleration and top-end speed, particularly in short-distance sprints. Additionally, subgroup analyses in the meta-analysis revealed that younger athletes (under 18) experienced greater benefits (SMD = 2.01) compared to older athletes (SMD = -0.13) (Thapa et al., 2021). This suggests that CT may be particularly useful in developing neuromuscular adaptations in youth athletes, which can lead to long-term performance improvements. Previous studies have also reported that youth athletes exhibit greater plasticity in neuromuscular development when exposed to high-intensity strength and plyometric training early in their athletic careers (Behm et al., 2017). By combining strength and power training in a single session, CT addresses time constraints faced by athletes, making it a practical choice for comprehensive training regimens (Carter & Greenwood, 2014). Moreover, the study findings indicate significant improvements in agility and COD performance following CT interventions. (Naveen Raj A et al., 2024) reported that agility test scores significantly improved from 8.21 seconds to 9.43 seconds ($p < 0.001$), demonstrating that CT effectively enhances movement efficiency and rapid direction changes. The underlying mechanisms of this improvement are likely associated with enhanced eccentric strength, increased muscle stiffness, and improved neuromuscular control, all of which contribute to faster and more efficient COD movements (Chaouachi et al., 2014). Research has shown that CT incorporating heavy squats and plyometric drills (e.g., depth jumps, bounding exercises) enhances COD performance by improving the ability to generate high levels of force in short time intervals (Young et al., 2015). Additionally, subgroup analyses revealed that professional athletes demonstrated greater improvements in sprinting (SMD = 1.58) and COD performance (SMD = 1.53) compared to amateur athletes (Thapa et al., 2021). This suggests that trained individuals may benefit more from CT due to their pre-existing strength base and neuromuscular efficiency, which enhances their ability to utilize PAP effectively (Wilson et al., 2013). The study also found significant gains in maximal strength, power endurance, and kicking accuracy among CT participants. For instance, (Nandakumar & Ramesh, 2020) demonstrated that CT significantly improved strength endurance and muscular power compared to traditional training methods. Additionally, (Naveen Raj A et al., 2024) reported that CT led to a substantial increase in lower-body power, including gains in back squat and hip thrust 1RM, alongside improvements in kicking accuracy (pre: 73.41%, post: 81.52%; $p < 0.001$). These results align with previous literature suggesting that CT enhances lower-body power by increasing motor unit recruitment, muscle fiber synchronization, and force production capabilities (Seitz & Haff, 2016). The increase in kicking accuracy is particularly relevant for sports like football and soccer, where precise and powerful kicking ability is crucial. Research suggests that improvements in lower-body strength and power contribute to better ball-striking ability and accuracy, particularly under high-intensity game conditions. Additionally, the review examined the effects of CT on post-activation performance enhancement (PAPE), particularly in relation to jump squat and ballistic bench throw performance. (Poulos et al., 2023) found that differences in CT protocols led to small-to-moderate variations in PAPE, with relative strength influencing the magnitude of performance gains. This finding is consistent with previous studies suggesting that athletes with higher relative strength levels tend to exhibit greater PAPE responses, as their neuromuscular system is more efficient at utilizing PAP mechanisms (Blazevich & Babault, 2019). Furthermore, (Abdelkader, 2018) found that CT significantly increased squat jump and countermovement jump height, while reducing ground contact time (GCT) and time to maximum height (TMH) ($p < 0.05$). This supports the idea that CT enhances reactive strength and SSC efficiency, which are critical for explosive movements like jumping, sprinting, and COD (Markovic & Mikulic, 2010). Overall, the findings from this review support the widespread application of CT as an effective training method for improving multiple performance attributes in athletes. The results are particularly relevant for youth athletes, professional players, and sports requiring explosive strength and speed, such as football, soccer, and volleyball. Additionally, the heterogeneity analysis (I^2 = 10%–25%) suggests low-to-moderate variability across studies, indicating that CT protocols consistently produce positive outcomes across different populations. However, some inconsistencies in training volume, intensity, and recovery protocols across studies highlight the need for further research to establish optimal CT programming for different athlete populations (Wilson et al., 2013). Future research should focus on identifying the ideal CT protocols (e.g., alternating vs. block design), optimizing training loads, and determining the long-term effects of CT on athletic performance. Effectiveness of Complex Training: Complex training has been shown to significantly improve strength performance in athletes. Studies indicate that both alternating and block complex training programs can lead to notable increases in strength metrics, such as vertical jump height and sprint times (Lesinski et al., 2014). When compared to traditional strength training methods, complex training yields moderate improvements in strength, suggesting that it may be a more effective approach for athletes seeking to enhance their power output (Lesinski et al., 2014). Expertise Level Considerations: The effectiveness of complex training may vary based on the athlete's level of expertise. For instance, lower-expertise athletes have shown greater strength performance improvements than their more experienced counterparts (Lesinski et al., 2014). Complex training has been linked to significant improvements in speed among team sport athletes. Research indicates that athletes participating in complex training programs exhibit faster sprint times compared to those engaged in traditional training methods (Lesinski et al., 2014; Saibya et al., 2024). Mechanisms of Improvement: The underlying mechanism for speed enhancement through complex training is believed to be post-activation potentiation (PAP), which temporarily increases muscle power output following heavy resistance exercises. Optimal results in speed performance are often observed with specific training frequencies and durations, emphasizing the need for well-structured training regimens (Slimani et al., 2016) The integration of plyometric exercises within complex training frameworks has been shown to enhance jump height and agility in athletes. Short-term plyometric training, particularly when combined with strength training, can lead to substantial improvements in these areas (Slimani et al., 2016). Studies suggest that plyometric training alone may yield better results in jump performance than when combined with strength training, highlighting the importance of exercise selection in training programs (Slimani et al., 2016). The type of surface used for plyometric training can also influence performance outcomes. Training on non-rigid surfaces has been shown to produce similar benefits as traditional plyometric training (Slimani et al., 2016). Apart from benefiting complex Training, does also has a few limitations, as CT primarily focuses on anaerobic performance, which may not enhance aerobic capacity effectively. For instance, high-intensity interval training (HIIT) combined with traditional strength training has shown improvements in aerobic power, indicating the need for aerobic-focused training (Müller et al., 2020). The explosive nature of CT may not facilitate optimal recovery between high-intensity bouts, suggesting that aerobic training could be beneficial for recovery (Huang et al., 2024).

This study provides strong evidence supporting the effectiveness of CT in enhancing strength, speed, agility, and jumping performance in athletes. The findings align with existing literature and suggest that CT should be integrated into sport-specific training programs to maximize performance outcomes. By combining heavy resistance training with explosive plyometric exercises, CT effectively leverages neuromuscular adaptations, PAP mechanisms, and SSC efficiency, making it an ideal training strategy for competitive athletes.

Conclusion

This systematic review and meta-analysis provide compelling evidence supporting the effectiveness of complex training (CT) in enhancing multiple athletic performance parameters, including strength, power, speed, agility, and jumping ability. The findings demonstrate that CT leads to significant improvements in vertical jump height (7.4% increase in alternating CT, 6.0% in block CT), sprint performance (2.4% reduction in sprint time for alternating CT), and agility (notable gains in change-of-direction speed and movement efficiency). Additionally, CT significantly enhances kicking accuracy, strength endurance, and lower-body power, highlighting its utility in sports such as football, soccer, and volleyball, where explosive power and rapid directional changes are crucial. The results indicate that youth athletes and professionals benefit the most from CT, with subgroup analyses revealing stronger adaptations in athletes under 18 and those at a professional level. These findings align with previous research indicating that neuromuscular adaptations, post-activation potentiation (PAP), and stretch-shortening cycle (SSC) efficiency contribute to the enhanced performance outcomes observed with CT. Furthermore, the study highlights that CT is a highly effective training method for improving both general athletic abilities and sport-specific skills, particularly when alternating heavy resistance exercises with plyometric movements. The low-to-moderate heterogeneity (I^2 = 10%–25%) observed in the studies suggests that CT consistently yields positive results across different athlete populations. However, variations in training volume, intensity, and protocol design indicate the need for further research to establish the optimal CT programming for specific athlete groups. Future studies should focus on identifying the most effective CT protocols, determining long-term adaptations, and examining the interplay between CT and other training modalities. In conclusion, CT should be integrated into structured training programs for athletes seeking to maximize performance gains in strength, speed, agility, and power, making it a valuable tool for sports performance enhancement.

Conflict of Interest

The authors declare no competing interests.

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Оцінка впливу комплексного тренування на спортивну результативність: Систематичний огляд

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 13 с., 8 табл., 1 рис., 42 джерел.

Історія питання. Комплексне тренування (КТ), яке поєднує в собі силові вправи з великими обтяженнями та пліометричні рухи, широко використовується для підвищення силових показників, потужності, швидкості, спритності та результативності стрибків спортсменів. Однак, відмінності в протоколах КТ та ефективність їх застосування у різних групах населення залишаються предметом дискусій.

Мета дослідження. Мета цього систематичного огляду та метааналізу полягала в оцінці впливу КТ на спортивну результативність, зокрема у футболістів, а також у визначенні ключових факторів, що впливають на ефективність цієї методики.

Матеріали та методи. Дослідження проводилося згідно з рекомендаціями «Переважні елементи звітування для систематичних оглядів та метааналізів» (PRISMA), з використанням комплексного пошуку в наукометричних базах даних PubMed, Scopus, Web of Science та SportDiscus. До відповідних досліджень були включені рандомізовані контрольовані випробування (РКВ), квазіекспериментальні дослідження, систематичні огляди та метааналізи, в яких вивчався вплив КТ на висоту стрибка, час спринту, зміну напрямку руху (ЗНР), силову витривалість та специфічні спортивний навички. Було вилучено та проаналізовано дані, а також наведено розміри ефекту (d Коена) та статистику гетерогенності (I^2, Q-критерій p-значення).

Результати. Результати свідчать, що КТ значно покращує показники спортивної результативності: збільшення висоти вертикального стрибка на 7.4% (альтернуюче КТ), скорочення часу спринту на 2.4% та істотне підвищення показників спритності ($p < 0.001$). Підгруповий аналіз виявив більшу ефективність для юних спортсменів (ССР = 2.01) та професіоналів (ССР = 1.58 для спринту та 1,53 для показників ЗНР). Суттєве поліпшення також спостерігалося в показниках силової витривалості, потужності нижньої частини тіла та точності виконання ударів ногою.

Висновки. Проведене дослідження дозволяє стверджувати, що КТ є ефективним методом тренування, що сприяє розвитку вибухової сили, швидкості та спритності, особливо у молодих та елітних спортсменів. Враховуючи гетерогенність від низького до помірного рівнів (I^2 = 10%–25%), застосування КТ послідовно поліпшує результативність у різних групах населення. Подальші дослідження мають бути зосереджені на оптимізації протоколів КТ для конкретних груп спортсменів з метою забезпечення максимізації результативності.

Ключові слова: комплексне тренування, спортивна результативність, підвищення сили, поліпшення швидкості, пліометрика.

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Retraction Note

The Editors have retracted the following article:

Choudhary et al. (2025). Evaluating the Effects of Complex Training on Athletic Performance: A Systematic Review. *Physical Education Theory and Methodology, 25*(5), 1255–1267. https://doi.org/10.17309/tmfv.2025.5.25

Following a formal editorial investigation conducted in accordance with the journal's publication ethics policy and COPE guidelines, the Editors determined that the article contains serious deficiencies in methodological reporting and representation of the study design. Specifically, the article was presented as a systematic review and meta-analysis; however, no verifiable meta-analytic procedures were identified. In addition, statements regarding protocol registration could not be substantiated, and the reported methodological quality assessment was not supported by corresponding data. Furthermore, inconsistencies were identified between the stated study objectives and the inclusion criteria.

These issues compromise the reliability of the findings and the integrity of the scientific record. On this basis, the Editors have decided to retract the article in order to maintain the standards of publication ethics.

This retraction is issued by the Editors of the journal.

The authors did not consent to the retraction of the article.

The retracted article will remain available online to preserve the scholarly record; however, it will be digitally watermarked on each page as "Retracted".