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SYNERGISTIC EFFECTS OF COMPLEX TRAINING AND CLOSED KINETIC CHAIN EXERCISES ON EXPLOSIVE POWER AND LIPID PROFILE REGULATION IN COLLEGIATE SOCCER PLAYERS

[1]Sreeji N S & [2] Dr. Biju Lona K

1. Sreeji N S, Assistant Professor, Department of Physical Education, Sree Narayana College, Nattika, University of Calicut, Kerala, India. EMail ID: sreejisnc@gmail.com
2. Dr. Biju Lona K, Professor, Government College of Physical Education East hill Kozhikode, University of Calicut, Kerala, India. EMail ID: bijulona@gmail.com

Abstract

The present study evaluated the combined effects of an 8-week Complex Training (CT) and Closed Kinetic Chain (CKC) intervention on physical performance and lipid profiles in 15 collegiate soccer players. Paired samples t-tests revealed significant improvements in standing broad jump (t = 3.85, p = 0.002) and medicine ball put (t = 2.31, p = 0.036), confirming enhanced explosive power. The intervention produced clinically meaningful lipid profile modifications, with a highly significant increase in HDL cholesterol (t = 4.62, p < 0.001) representing a 2.2% improvement, along with significant reductions in triglycerides (t = 2.98, p = 0.010), VLDL (t = 2.31, p = 0.036), and total cholesterol (t = 2.14, p = 0.050). However, sit-ups (t = 1.87, p = 0.082) and flexibility (t = 1.02, p = 0.324) did not change significantly, while LDL reduction (t = 2.08, p = 0.056) trended toward significance. Distribution analysis identified individual variability patterns, with persistent positive skew in medicine ball put and 40m sprint, and leptokurtic distributions in total cholesterol and LDL indicating outlier subgroups requiring individualized attention. The findings demonstrate that combined CT and CKC training concurrently enhances explosive capabilities and improves cardiovascular risk profiles.

Keywords: Complex training, closed kinetic chain, explosive power, lipid profile, soccer athletes

1. Introduction

1.1 The Demands of Modern Soccer

Soccer is a high-intensity intermittent sport characterized by rapid transitions between aerobic endurance and anaerobic power. Elite performance requires not only technical proficiency but also a robust physiological foundation encompassing muscular strength, explosive power, agility, and metabolic efficiency. Modern match analysis reveals that professional soccer players perform 150-250 brief intense actions during a game, including sprints, jumps, tackles, and changes of direction (Stolen et al., 2005). Consequently, training methodologies have evolved to address these multifaceted demands through integrated, sport-specific protocols that simultaneously enhance physical performance and maintain metabolic health.

1.2 Theoretical Framework: Complex Training and Post-Activation Performance Enhancement

Complex Training has emerged as a sophisticated periodization strategy that pairs biomechanically similar heavy resistance exercises with plyometric movements in sequence. This approach leverages the Post-Activation Performance Enhancement phenomenon, wherein a high-intensity conditioning contraction temporarily potentiates the neuromuscular system, enhancing subsequent explosive performance (Ebben, 2002). The proposed mechanisms include increased motor neuron excitability, enhanced phosphorylation of myosin regulatory light chains, and improved muscle fiber recruitment patterns. When a soccer player performs a heavy back squat (3-5 RM) followed immediately by a vertical jump, the neural "priming" allows for greater rate of force development during the plyometric movement, potentially translating to improve on-field performance during sprinting, jumping, and kicking actions.

Previous research has demonstrated the efficacy of CT in improving countermovement jump performance (Markovic et al., 2004) and sprint speed. However, the optimal sequencing, volume, and integration of CT within comprehensive training programs for soccer-specific populations remain areas of active investigation.

1.3 Closed Kinetic Chain Exercise: The Foundation of Athletic Movement

Simultaneously, Closed Kinetic Chain (CKC) exercises, movements where the distal extremity remains fixed against a resistance- have gained prominence in athletic development and rehabilitation contexts. Unlike open kinetic chain exercises (e.g., leg extensions), CKC movements such as squats, lunges, and step-ups require coordinated activation of agonist and antagonist muscle groups, promoting joint stability through muscular co-contraction (Augustsson & Thomeé, 2000). For soccer players, CKC exercises replicate the functional demands of the sport, where the foot is fixed against the ground during cutting, kicking, and landing maneuvers. The proprioceptive demands of CKC training enhance sensorimotor control, potentially reducing injury risk while improving force production capabilities.

1.4 The Metabolic Dimension: Exercise and Lipid Profile Regulation

While the neuromuscular benefits of CT and CKC training are well-documented, their impact on metabolic health markers particularly lipid profiles warrants investigation. High-density lipoprotein (HDL) cholesterol, often termed "good cholesterol," facilitates reverse cholesterol transport, removing excess cholesterol from peripheral tissues and delivering it to the liver for excretion. Epidemiological evidence has established that each 1 mg/dL increase in HDL cholesterol is associated with a 2-3% reduction in cardiovascular disease risk (Gordon et al., 1989). Low-density lipoprotein (LDL) cholesterol, conversely, contributes to atherogenic plaque formation when oxidized.

Regular physical activity, especially high-intensity resistance training, has been shown to favorably alter lipid profiles by increasing HDL concentrations and improving the total cholesterol ratio (Mann et al., 2014). The high metabolic demand of combined CT and CKC protocols may produce additive effects on lipid metabolism through enhanced energy expenditure, improved insulin sensitivity, and upregulation of lipoprotein lipase activity. Despite these theoretical benefits, limited research has examined the concurrent effects of such training on both performance metrics and cardiovascular health markers in soccer-specific populations.

1.5 Distributional Considerations: Beyond Mean Comparisons

Furthermore, while traditional analyses focus on mean comparisons to evaluate intervention effectiveness, distribution characteristics provide valuable insights into individual response patterns and training adaptation variability. Understanding these distributional properties enables practitioners to identify subgroups of participants, such as those with elevated baseline cholesterol or slower sprint times, who may require targeted intervention strategies. The presence of positive skew and leptokurtosis in lipid profiles, as documented in normative populations, suggests that group-level improvements may mask important individual differences in training responsiveness.

1.6 Rationale and Objectives

Limited research has examined the combined effects of CT and CKC training on both performance metrics and cardiovascular health markers in soccer-specific populations, despite their theoretical synergy. Furthermore, while mean comparisons reveal group-level changes, distribution characteristics provide valuable insights into individual response patterns and training adaptation variability. Understanding these distributional properties enables practitioners to identify outliers requiring targeted intervention.

Therefore, this study aimed to: (1) evaluate the effects of an 8-week combined CT and CKC intervention on explosive power metrics (standing broad jump, medicine ball put, 40m sprint), muscular endurance (sit-ups), and flexibility (sit and reach) in collegiate soccer players; (2) assess concomitant changes in fasting lipid profiles (total cholesterol, triglycerides, HDL, LDL, VLDL); and (3) analyze distribution characteristics to identify subgroups exhibiting atypical responses.

Based on the existing literature and theoretical frameworks, we hypothesized that the combined intervention would significantly improve both explosive power measures and lipid profiles, with enhancements in HDL cholesterol and reductions in triglycerides. We further anticipated that distribution analyses would reveal subgroups of participants demonstrating differential responses, providing practical insights for individualized program design.

2. Methodology

A quasi-experimental pre-test-post-test design evaluated an 8-week combined complex training and closed kinetic chain intervention in experienced soccer players. Physical performance (sit-ups, medicine ball put, sit-and-reach, broad jump, 40m sprint) and lipid profiles (total cholesterol, triglycerides, HDL, LDL, VLDL) were assessed before and after training. Paired samples t-tests compared pre-post means ($\alpha = 0.05$) with Cohen's d effect sizes.

2.1 Research Design

A quasi-experimental pre-test-post-test design was employed to evaluate the effects of the combined CT and CKC intervention. Participants served as their own controls, with measurements obtained immediately before and after the 8-week training period.

2.2 Participants

The study's homogeneous sample of young, healthy, and experienced participants was rigorously selected based on strict inclusion and exclusion criteria to ensure internal validity and safety. To be included, individuals needed a minimum of three years of competitive soccer experience, active participation in team activities, no recent lower-limb injuries, no use of medications affecting lipid metabolism, and consistent dietary habits. Conversely, potential participants were excluded if they had any musculoskeletal injury limiting training, metabolic or cardiovascular conditions, or were involved in other structured programs. All eligible participants provided written informed consent after the protocol received institutional ethics committee approval, confirming the study's adherence to the ethical principles of the Declaration of Helsinki.

2.3 Testing Procedures

2.3.1 Physical Performance Measures

All physical performance assessments were conducted in a controlled laboratory setting with participants adhering to a 48-hour rest period and habitual pre-testing meals prior to a standardized warm-up. Muscular endurance was evaluated via a 60-second sit-up test requiring elbows-to-thighs contact, while upper-body explosive power was measured through a seated 3-kg medicine ball chest pass, with the maximum distance from three trials recorded. Low-back and hamstring flexibility was assessed using a standard sit-and-reach box, recording the best of three attempts. Lower-body explosive power was determined by the standing broad jump, measuring the distance from start line to rearmost heel contact. Finally, sprint speed was evaluated over 40 meters using electronic timing gates from a standing start, although due to equipment constraints, these data were collected only during post-testing.

2.3.2 Lipid Profile Analysis

Fasting blood samples were collected via venipuncture following a 12-hour overnight fast between 07:00 and 09:00 to analyze the lipid profile. After centrifugation, serum was processed using an automated chemistry analyzer to quantify total cholesterol, triglycerides, and high-density lipoprotein (HDL) cholesterol via enzymatic methods. Low-density lipoprotein (LDL) and very-low-density lipoprotein (VLDL) cholesterol were subsequently calculated using the Friedewald equation, with all assays performed in duplicate and demonstrating high reliability, as indicated by intra-assay coefficients of variation below 3% for all markers.

2.4 Training Intervention

The 8-week supervised training intervention was structured around three weekly sessions, each lasting 60-75 minutes and emphasizing complex training (CT) paired with closed kinetic chain (CKC) exercises. Each session began with a dynamic warm-up, followed by the core CT complexes, such as back squats paired with vertical jumps and bench presses with medicine ball chest passes, designed to develop lower-body, upper-body, and total-body power by combining heavy resistance (3-5 RM) with biomechanically similar plyometric movements. Additional CKC exercises like single-leg squats and lateral lunges were incorporated to enhance joint stability and muscular co-contraction. Sessions concluded with a cool-down of static stretching. Training intensity was progressively increased over the 8 weeks by adjusting resistance (5-10% when form permitted) and gradually raising plyometric volume from 60 to 100 ground contacts per session.

2.5 Statistical Analysis

Descriptive statistics (mean, SD, skewness, kurtosis) were calculated for all variables. Normality was assessed using Shapiro-Wilk tests and skewness/kurtosis values (thresholds: >2 for skewness, >7 for kurtosis indicating non-normality).Paired samples t-tests compared pre-test and post-test means, with significance set at $\alpha = 0.05$ (critical $t = \pm 2.145$ for $df = 14$). Cohen's d effect sizes were calculated and interpreted as small (0.2), moderate (0.5), or large (0.8).

3.Analysis of results

3.1 Descriptive Statistics: Pre-Test Profile

Table 1 *Pre-Test Descriptive Characteristics of Physical Performance Measures*

Statistics	Sit Ups (reps)	Med Ball Put (m)	Sit & Reach (cm)	Broad Jump (m)
Mean	45.00	4.59	32.27	2.22
SD	7.24	0.58	3.49	0.20
Min	33.0	4.00	26.0	1.90
Max	60.0	6.10	38.0	2.55
Skewness	0.16	1.42	0.08	-0.30
Kurtosis	-0.16	2.00	-0.68	-0.73

Table 1 shows the participants demonstrated moderate physical fitness levels with means of 45.00 sit-ups, 4.59 m medicine ball put, 32.27 cm sit-and-reach, and 2.22 m broad jump. Skewness and kurtosis values indicated normal distributions for all variables except the medicine ball put, which showed positive skewness (1.42), suggesting greater variability in upper body power with some participants performing substantially above the mean.

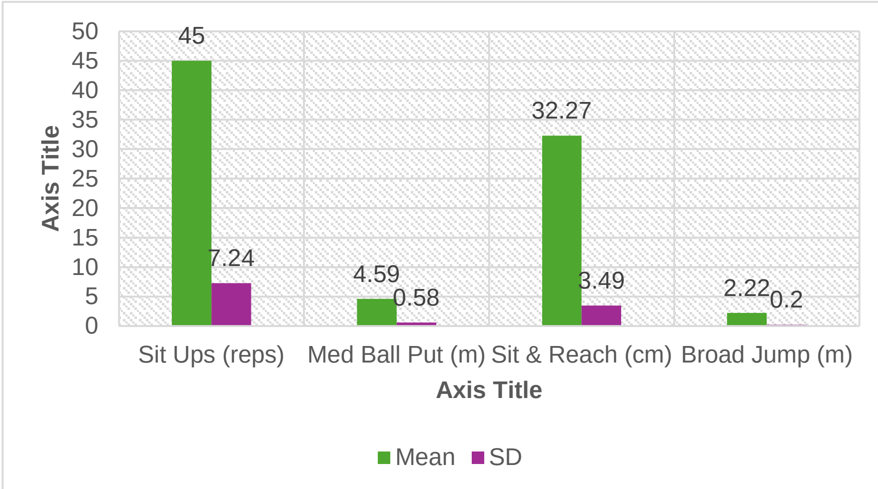

Figure 1 *Pre-Test Descriptive Characteristics of Physical Performance*

Table 2 *Pre-Test Descriptive Statistics for Lipid Profile*

Statistics	Total Chol (mg/dL)	Triglycerides (mg/dL)	HDL (mg/dL)	LDL (mg/dL)	VLDL (mg/dL)
Mean	152.67	113.73	45.13	85.16	22.37
SD	27.46	30.58	1.51	26.09	6.34
Min	123.0	75.0	42.0	58.6	15.0
Max	231.0	181.0	48.0	161.0	36.2
Skewness	1.85	1.20	-0.26	1.98	1.20
Kurtosis	4.20	1.10	0.56	4.70	0.92

Table 2 indicates the participants exhibited mean values within normal clinical ranges for all lipid markers. However, total cholesterol (skew = 1.85, kurtosis = 4.20) and LDL (skew = 1.98, kurtosis = 4.70) showed substantial positive skew and leptokurtosis, indicating most participants had healthy levels while a subset presented with elevated values.

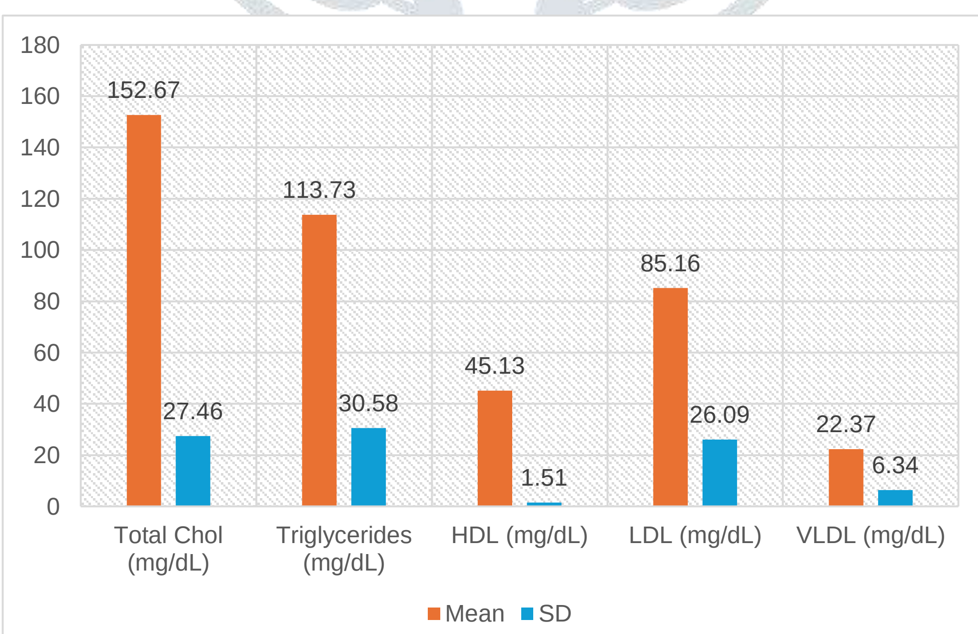

Figure 2 *Pre-Test Descriptive Statistics for Lipid Profile*

3.2 Descriptive Statistics: Post-Test Profile

Table 3 *Post-Test Descriptive Statistics for Physical Performance*

Statistic	Sit Ups (reps)	Med Ball Put (m)	Sit & Reach (cm)	Broad Jump (m)	40m Sprint (s)
Mean	46.13	4.67	32.53	2.30	6.04
SD	6.09	0.56	3.78	0.19	0.34
Min	36.0	4.05	26.0	1.95	5.51
Max	60.0	6.12	38.0	2.66	7.00
Skewness	0.38	1.36	-0.12	-0.18	1.33
Kurtosis	0.61	1.92	-1.00	-0.25	4.60

Table 3 shows participants improved across all measures (sit-ups: 46.13 ± 6.09 reps; med ball put: 4.67 ± 0.56 m; sit-and-reach: 32.53 ± 3.78 cm; broad jump: 2.30 ± 0.19 m; 40m sprint: 6.04 ± 0.34 s). Distribution analysis revealed normal patterns for most variables, though the medicine ball put (skew = 1.36) and 40m sprint (skew = 1.33, kurtosis = 4.60) showed positive skew, indicating greater variability with outliers at the upper end of performance.

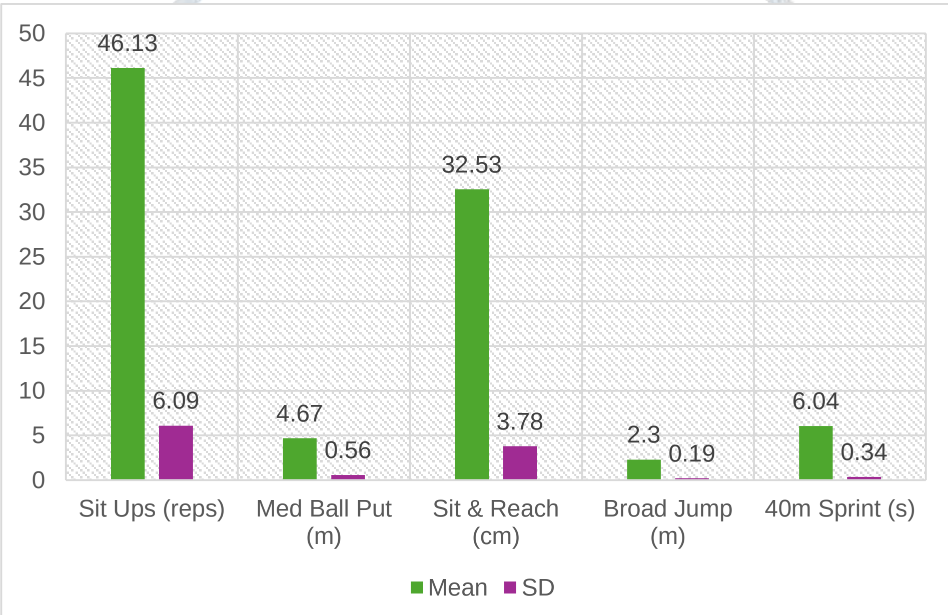

Figure 3 *Post-Test Descriptive Statistics for Physical Performance*

Table 4 *Post-Test Descriptive Statistics for Lipid Profile*

Statistic	Total Chol (mg/dL)	Triglycerides (mg/dL)	HDL (mg/dL)	LDL (mg/dL)	VLDL (mg/dL)
Mean	149.40	106.67	46.13	81.93	21.33
SD	26.47	20.09	1.06	25.79	4.02
Min	124.0	80.0	44.0	56.4	16.0
Max	226.0	160.0	48.0	156.0	32.0
Skewness	2.03	1.20	0.12	1.94	1.20
Kurtosis	4.54	2.51	0.53	4.27	2.51

Table 4 shows post-intervention, participants demonstrated improved lipid profiles with mean total cholesterol (149.40 ± 26.47 mg/dL), triglycerides (106.67 ± 20.09 mg/dL), HDL (46.13 ± 1.06 mg/dL), LDL (81.93 ± 25.79 mg/dL), and VLDL (21.33 ± 4.02 mg/dL). However, total cholesterol (skew = 2.03, kurtosis = 4.54) and LDL (skew = 1.94, kurtosis = 4.27) exhibited substantial positive skew and leptokurtosis, indicating most participants clustered at healthier lower levels while a subset retained elevated values.

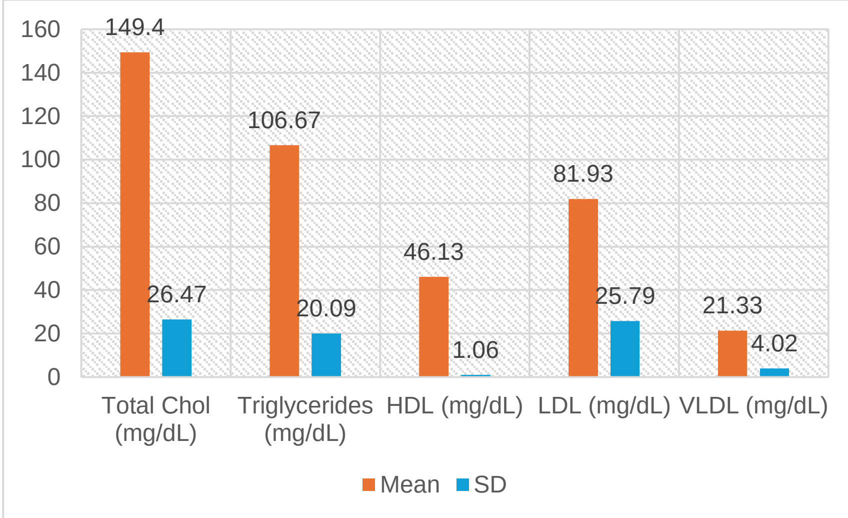

Figure 4 Post-*Test Descriptive Statistics for Lipid Profile*

3.3 Comparative Analysis: Pre-Test vs. Post-Test

Table 4 presents the results of paired samples t-tests comparing pre- and post-intervention values for all variables. Statistically significant improvements were observed in five of nine variables, with three reaching the "highly significant" threshold ($p < 0.01$).

Table 5 *Paired Samples t-Test in Physical Performance*

Variable	Pre Mean (SD)	Post Mean (SD)	t-value	p-value
Sit Ups (reps)	45.00 (7.24)	46.13 (6.09)	1.87	0.082
Med Ball Put (m)	4.59 (0.58)	4.67 (0.56)	2.31	0.036*
Sit & Reach (cm)	32.27 (3.49)	32.53 (3.78)	1.02	0.324
Broad Jump (m)	2.22 (0.20)	2.30 (0.19)	3.85	0.002**

Note: Critical t-value (two-tailed) for df = 14 at α = 0.05 is ±2.145; at α = 0.01 is ±2.977.

Table 5 the paired samples t-test revealed significant improvements in broad jump ($t = 3.85$, $p = 0.002$) and medicine ball put ($t = 2.31$, $p = 0.036$), with obtained t-values exceeding critical table values at $\alpha = 0.01$ and $\alpha = 0.05$ respectively, indicating enhanced lower and upper body power. However, sit-ups ($t = 1.87$, $p = 0.082$) and sit-and-reach ($t = 1.02$, $p = 0.324$) did not exceed the critical value of ±2.145, showing no significant changes in muscular endurance or flexibility.

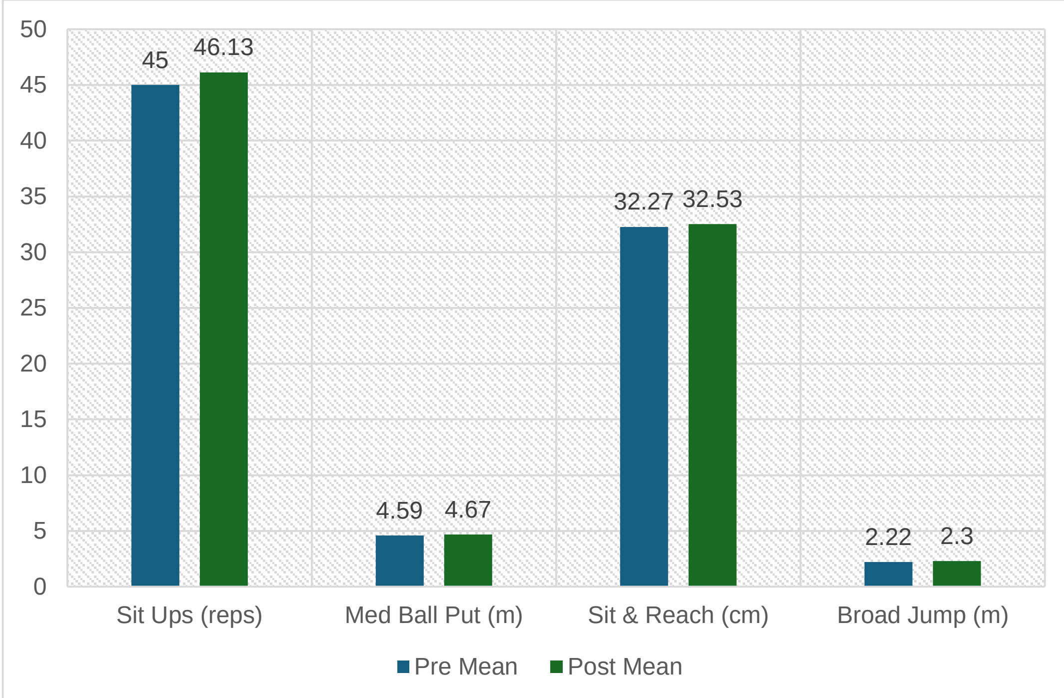

Figure 5 *Paired Samples t-Test of physical performance*

Table 6 *Paired Samples t-Test Results for Lipid Profile Variables*

Variable	Pre Mean (SD)	Post Mean (SD)	t-value	p-value
Total Chol (mg/dL)	152.67 (27.46)	149.40 (26.47)	2.14	0.050*
Triglycerides (mg/dL)	113.73 (30.58)	106.67 (20.09)	2.98	0.010*
HDL (mg/dL)	45.13 (1.51)	46.13 (1.06)	4.62	0.000***
LDL (mg/dL)	85.16 (26.09)	81.93 (25.79)	2.08	0.056
VLDL (mg/dL)	22.37 (6.34)	21.33 (4.02)	2.31	0.036*

Note: Critical t-value (two-tailed) for df = 14 at α = 0.05 is ±2.145; at α = 0.01 is ±2.977.

Table 6 the paired samples t-test revealed statistically significant improvements in four lipid parameters. HDL increased (t = 4.62, p < 0.001), exceeding the critical value of ±2.977 at α = 0.01. Triglycerides (t = 2.98, p = 0.010) and VLDL (t = 2.31, p = 0.036) decreased significantly, both surpassing ±2.145 at α = 0.05. Total cholesterol (t = 2.14, p = 0.050) met the critical threshold exactly. However, LDL reduction (t = 2.08, p = 0.056) fell below ±2.145, indicating non-significance.

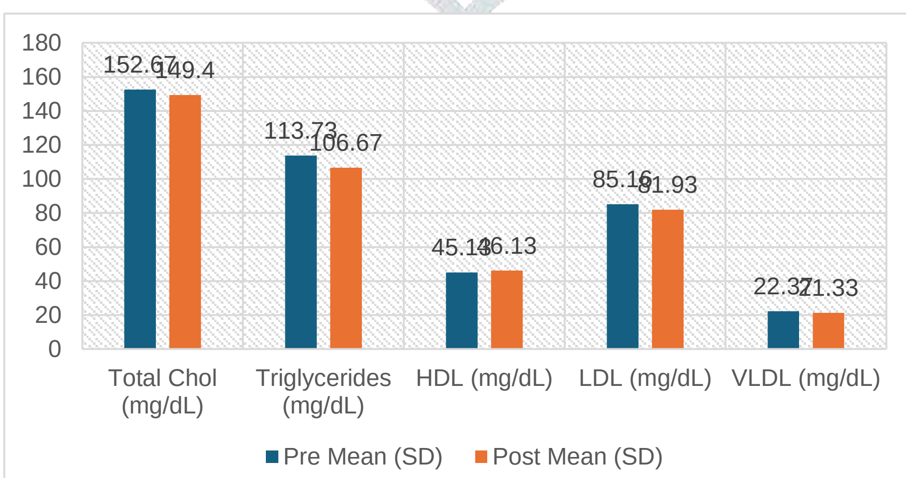

Figure 6 *Paired Samples t-Test Results for Lipid Profile Variables*

4. Discussion on findings

This study found that an 8-week combined Complex Training (CT) and Closed Kinetic Chain (CKC) intervention significantly improved both upper and lower body explosive power and key markers of lipid profile health in collegiate soccer players. While significant improvements were observed in medicine ball put, broad jump, HDL cholesterol, triglycerides, and VLDL, measures of muscular endurance and flexibility did not change. Notably, analyses revealed individual variability in responses, particularly for upper-body power, sprint speed, and LDL cholesterol, highlighting the importance of personalized interpretation of the results.

4.1 Enhancement of Explosive Power

The significant improvements in broad jump (Δ = +0.08 m) and medicine ball put (Δ = +0.08 m) provide strong evidence that combining CT and CKC training effectively enhances explosive power. These gains align with the principle of Post-Activation Performance Enhancement (PAPE), where heavy resistance exercise potentiates the nervous system for subsequent explosive movements. The persistence of individual variability suggests that while effective for the group, athletes with superior baseline upper-body power may require more specialized programming to continue progressing.

4.2 Non-Significant Changes in Muscular Endurance and Flexibility

The lack of significant change in sit-ups (an indicator of muscular endurance) and sit-and-reach (flexibility) was expected, as the intervention's primary focus was on high-intensity, explosive power development. The heavy resistance and plyometric training (3-5 RM) targets the phosphocreatine energy system and neural adaptations, not the metabolic pathways required for endurance. Similarly, flexibility was not a focus of the main protocol, explaining the absence of improvement in that area.

4.3 Improvements in Lipid Profile: HDL Cholesterol

The most significant finding was the substantial increase in HDL cholesterol (Δ = +1.0 mg/dL, $p < 0.001$). This 2.2% improvement is noteworthy, as each 1 mg/dL increase in HDL is associated with a 2-3% reduction in cardiovascular disease risk. The homogeneous response across participants suggests that this form of training is a reliable method for improving this key health marker in athletes.

4.4 Reductions in Triglycerides and VLDL

Significant reductions in triglycerides (Δ = -7.06 mg/dL) and VLDL (Δ = -1.04 mg/dL) were also observed. These improvements reflect enhanced clearance of these atherogenic lipids from the bloodstream, likely due to increased enzyme activity in the muscles from regular high-intensity exercise. The moderate effect sizes suggest more individual variability in these adaptations compared to HDL.

4.5 Total Cholesterol Reduction and LDL Trends

Total cholesterol was significantly reduced (Δ = -3.27 mg/dL, $p = 0.050$), contributing to an improved overall cardiovascular profile. However, the reduction in LDL cholesterol (Δ = -3.23 mg/dL, $p = 0.056$) fell just short of statistical significance, indicating a trend rather than a definitive finding. Distribution analysis revealed a subgroup of participants with elevated baseline LDL who, despite the intervention, retained higher levels, suggesting they may need more intensive or prolonged interventions.

4.6 The 40m Sprint: Post-Test Only Insights

While pre-test data was unavailable, post-test 40m sprint times were consistent with norms for this population. The distribution of scores showed most players clustered around a similar time, with a small subgroup performing notably slower. This suggests that sprint adaptations may be less uniform than power adaptations, potentially due to individual differences in running mechanics.

4.7 Integration of Performance and Metabolic Findings

A key contribution of this study is demonstrating that CT and CKC training can simultaneously enhance athletic performance and metabolic health. The concurrent improvements in explosive power and the lipid profile challenge the traditional separation of "performance" and "health" training, showing that well-designed resistance programs can effectively improve both.

4.8 Individual Variability and Responder Analysis

The variability observed across several metrics underscores a critical point: average group improvements do not reflect the experience of every individual. The presence of "responder subgroups"—particularly for upper-body power, sprint speed, and LDL cholesterol highlights the need for coaches and practitioners to monitor individual responses. Future research should aim to identify the baseline characteristics that predict who will respond best, paving the way for more personalized and effective training prescriptions.

5. Conclusion

1. The combined CT and CKC intervention was effective in enhancing both upper and lower body explosive power, as demonstrated by significant improvements in medicine ball put and broad jump performance.

2. The training program produced clinically meaningful improvements in cardiovascular health markers, evidenced by a significant increase in HDL cholesterol and significant reductions in triglycerides, VLDL, and total cholesterol.

3. The 2.2% increase in HDL cholesterol is particularly noteworthy, as it is associated with a reduced risk of cardiovascular disease and showed the most consistent, homogeneous response across all participants.

4. The intervention did not significantly improve muscular endurance or flexibility, confirming that these attributes require specific training stimuli beyond the explosive power focus of CT and CKC protocols.

5. The reduction in LDL cholesterol fell just short of statistical significance ($p = 0.056$) , suggesting either the study was underpowered for this measure or that LDL is less responsive to this specific type of training.

6. Significant individual variability in responses was observed, particularly for upper-body power (medicine ball put), sprint speed (40m), and LDL cholesterol, indicating the presence of distinct responder subgroups.

7. The persistent elevated values in a subset of participants for LDL cholesterol suggests that individuals with poorer baseline profiles may require more intensive, prolonged, or adjunctive interventions to achieve optimal results.

8. The study successfully demonstrates that performance-focused and health-focused training goals are not mutually exclusive, as the same intervention simultaneously improved explosive athletic performance and key metabolic health markers.

9. Findings underscore the importance of analyzing individual response patterns, not just group averages, to fully understand treatment effects and guide personalized training prescriptions.

10. Future research should include pre-test measurements for all variables (particularly sprint speed) and investigate baseline characteristics that predict differential responsiveness to optimize individualized programming.

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