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Effects of 12 Weeks Core Strength Training on Bio-motor Fitness Abilities among College Level Soccer Players

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Abstract This study aimed to evaluate the effects of a 12-week core strength training (CST) program on bio-motor fitness components among college-level male soccer players aged 18 to 23 years. **Methods**: Sixteen male soccer players participated in this study. They were divided into an experimental group that underwent a CST program and a control group that maintained their regular training routine. The CST program, integrated into the regular soccer training schedule, included exercises such as planks, bridges, and various forms of crunches, progressively increasing in intensity. Upper body explosive strength was assessed using a backward medicine ball throw, lower body explosive power using a standing long jump and countermovement jump, and change of direction speed using an agility test. Sprint performance was measured with 15m and 30m linear sprint tests. **Results**: The CST group showed significant improvements across all measured variables. Notable percentage changes were observed in the 15m sprint (4.08%), 30m sprint (1.56%), upper body strength (6.87%), standing long jump (4.66%), countermovement jump (15.69%), and change of direction speed (12.35%). Effect sizes indicated substantial enhancements in standing long jump ($g = 1.634$, $p = 0.001$), countermovement jump ($g = 7.110$, $p < 0.001$), and change of direction speed ($g = 3.142$, $p = 0.001$). The control group did not exhibit significant changes in any variables. **Conclusion**: A 12-week core strength training program, consisting of three sessions per week, significantly improved bio-motor fitness components in college-level soccer players aged 18 to 23 years. These findings support the inclusion of CST in soccer training regimens to enhance athletic performance.

Keywords Core Strength Training, Bio-motor Fitness, Soccer Players, Standing Long Jump, Countermovement Jump

1. Introduction

Core Stability Training (CST) is a key component in sports conditioning, particularly in soccer, as it has been shown to enhance athletic performance and contribute to injury prevention in athletes [1,2]. The core muscles, including those around the lumbar spine and pelvis, play a vital role in stabilizing the body during dynamic movements. This stabilization is essential for the efficient transfer of forces through the kinetic chain, contributing to overall athletic performance and reducing injury risk [3,4]. This is very important, not just for injury prevention but also for efficiency in the biomechanical execution during any high-intensity sport, which allows an athlete to give a peak performance without any fear of injury [5-7]. These activities require strength, precision, high amounts of power transfer, and body control, all significantly augmented by a solid and stable core [4-6]. In addition, a well-conditioned core has been proven to aid in appropriate posture and alignment while playing, translating into better handling of the game's physical demands, whether in a training or competitive environment [4,8,9]. CST is also noted to contribute to key performance metrics like sprint times, agility, and explosive power—essential attributes for soccer players. Core strength is the foundation that allows the body to put strong and explosive movements into motion—something that often characterizes the pace of actions in soccer. It is a significant factor, especially during the acceleration phases of running, which lets athletes reach maximum speed more quickly [6,8,9].

Furthermore, the ability to make appropriate alterations in the path of motion and balance during such rapid directional changes is dominantly based on core muscle strength and reactivity, which enhances agility and maintains body balance and control against a rapid directional change [8,10,11]. However, despite this well-documented advantage of core training, more research is still needed on the exact quantification of CST benefits to the physical fitness components of soccer players. Studies in sports sciences found that there needed to be more information on the quantification of CST's impact on the physical fitness components of soccer players. While numerous studies highlight the general advantages of physical conditioning, only a few have focused on isolating the effects of core-strength training on performance metrics like sprint speed, agility, and power [12,13]. For instance, research has shown that core-strength training improves speed and agility in young male football players [14]. Similarly, other studies have demonstrated that neuromuscular performance and agility significantly improve in youth soccer players when core-strength training is conducted on unstable surfaces [13,15]. This justifies the identified research gap for focused studies, which would yield direct benefits concerning core training in a sport-specific context like soccer.

This study aims to fill this gap by implementing a systematic 12-week core strength training program and assessing its specific effects on bio-motor fitness abilities in college-level soccer players. The hypotheses of this study are: It was hypothesised that the core strength training program significantly improved linear sprint, upper body strength, standing long jump, countermovement jump and change of direction speed of college-level male soccer players.

2. Materials and Methods

Participants

The subjects of the study were 16 soccer players whose ages ranged from 18 to 23 years; all the subjects were male, originating from the SRM Institute of Science and Technology, Chennai, and participating in soccer as a part of the university sports quota. The sample size calculation was done using the Cohen’s f (f=0.4) for within-between interaction in the repeated measures design, with the desired statistical power of 0.80. More specifically, concerning the study’s selection criteria the following qualifications had to be fulfilled in order to be included in the study: Participants were required to engage in regular soccer practice for a minimum of three hours per day. Some of the conditions that were excluded were any previous musculoskeletal injury or any condition that would hinder the ability to do core strength exercises. Concerns on the possible risks or benefits arising from the study were explained to all the participants and each of them signed a written informed consent. The study sample was randomly divided into an Experimental group (n=8) that remained with soccer training along with core strength training. The active control group (n=8) remained active by going back to their soccer practice but did not participate in any core strength training. Table 1 summarizes the demographic characteristics of the participants.

Table 1. Demographic Information of Core Strength Training Group (CSTG) and Active Control Group (ACG)

	CSTG (n=8)	ACG (n=8)	p-value*
Years	20.53 ± 1.86	20.21 ± 1.60	0.741
Body weight (kg)	63.22 ± 3.37	66.16 ± 3.15	0.242
Height (cm)	174.40 ± 4.03	173.14 ± 5.06	0.412

CSTG: Core Strength Training Group and ACG: Active Control Group; *Independent t tests

Intervention

The specific intervention implemented in the experimental group’s core strength training program was to perform exercises that targeted the strengthening of the core muscles. The soccer program was implemented alongside their soccer practice for 12 weeks at an interval of three times a week. Some of the movements that were performed in each session are planks, bridges besides various types of crunches where the intensity of the exercises was programmed to gradually be increased, within the successive meetings. In the set up of the 12-week plans the first week was considered as the familiarization week. In this week, the participants were acquainted with the exercise form and the correct manner in which they should be performed to avoid injuries and for enhanced efficiency. The familiarization period ensured that participants became acquainted with the exercises so that they may understand the correct form and proper way of exercising. Table 2 provides a detailed overview of the weekly core strength training regimen.

All the instructions as well as supervision of the training were done directly by a certified strength and conditioning expert. Here the expert made sure that each participant practiced as instructed and modified the complexity and the degree of challenge depending on abilities. Such professional advice was important in minimizing the risks of getting injuries and in making sure that the exercise of core strength training provided the benefits that were desired and planned in the study.

Outcome Measure Procedure

Assessments of bio-motor fitness abilities were conducted at baseline and after the 12-week intervention period. These assessments included measures of linear sprint, strength, endurance, agility, and flexibility. A week prior to the baseline measurement, the main fitness tests were carried out by the participants, but they underwent two warm-up sessions to familiarise them with the tests. Data pertaining to the demographic profile of the subjects were gathered during the familiarization sessions. Participants were advised against indulging in any form of exercise and taking alcohol for 24 hours before the test.

Linear Sprint 15 m & 30 m Test

Linear sprint performance was measured with the help of 15m and 30m sprint tests on the 400m outdoor standard athletic track. In view of this, the participants had three attempts at each distance excluding the first attempt and the best were used in the analysis. Before the tests, the participants were required to warm up for not less than ten minutes; this warmed up involved jumping jacks, power skips and others; this was to increase circulation and to minimize chances of injuries. For the time keeping, cones were used to draw starting and finishing lines with the aid of a digital watch. The results were smoother with a higher level of accuracy. To ensure standardisation of the various activities, a certified tester offered the instructions as well as managed the stopwatch. Standing in front of the starting line, each sprint started from the standing position. Timing was taken when the participant moved over the start line and stopped when the participant reached the 15 meter and 30 meter mark respectively. The ICC, with a 95% confidence interval (CI), was 0.83 (0.84 – 0.92) for the 10-meter sprint and 0.86 (0.85 – 0.96) for the 30-meter sprint. The recovery period between the trials was set at 2-3 minutes to allow the heart rate to return to normal [16].

Table 2. Core Strength Training (CST) Performed by Experimental Group

Week	Day 1	Day 2	Day 3
1	Planks (3x30s, 30s rest)	Bridges (3x15, 30s rest)	Crunches (3x20, 30s rest)
2	Planks (3x40s, 30s rest)	Bridges (3x20, 30s rest)	Crunches (3x25, 30s rest)
3	Planks (3x45s, 30s rest)	Bridges (3x25, 30s rest)	Bicycle Crunches (3x20, 30s rest)
4	Side Planks (3x30s each side, 30s rest)	Single-leg Bridges (3x15 each leg, 30s rest)	Leg Raises (3x15, 30s rest)
5	Side Planks (3x40s each side, 30s rest)	Single-leg Bridges (3x20 each leg, 30s rest)	Leg Raises (3x20, 30s rest)
6	Side Planks (3x45s each side, 30s rest)	Single-leg Bridges (3x25 each leg, 30s rest)	Russian Twists (3x30, 30s rest)
7	Planks with Arm Lift (3x30s, 30s rest)	Bridges with Leg Lift (3x15 each leg, 30s rest)	Flutter Kicks (3x30s, 30s rest)
8	Planks with Arm Lift (3x40s, 30s rest)	Bridges with Leg Lift (3x20 each leg, 30s rest)	Flutter Kicks (3x40s, 30s rest)
9	Planks with Arm Lift (3x45s, 30s rest)	Bridges with Leg Lift (3x25 each leg, 30s rest)	Mountain Climbers (3x30s, 30s rest)
10	Planks (3x1min, 30s rest)	Single-leg Bridges (3x30 each leg, 30s rest)	V-ups (3x15, 30s rest)
11	Side Planks (3x1min each side, 30s rest)	Single-leg Bridges (3x35 each leg, 30s rest)	Russian Twists (3x40, 30s rest)
12	Planks with Arm and Leg Lift (3x1min, 30s rest)	Bridges with Leg Lift (3x30 each leg, 30s rest)	Bicycle Crunches (3x30, 30s rest)

Upper Body Strength (Backward Medicine Ball Throw)

In this case, the backward medicine ball throw was used to determine upper body explosive ST. The exercise was carried out on a large open space of an available ground for safety measures to be observed. This study involved three trials for each participant, with the analysis using the average of the three throws recorded. Before the experiment, all the participants developed a set of exercises that had to be performed before the start of the test, in particular, stretching exercises and movements aimed at the upper extremities as a preventive measure against injuries. A specific line for throwing was drawn on the ground and subjects positioned themselves with their backs towards the direction in which they needed to throw. With two hands, participants took a standard grip of a medicine ball in front of them and got advised to bend their knees and then throw the ball as high and backward as they could. Measuring of the distance from the throwing line to the point where the ball touched the ground was done using a measuring tape. There were enough breaks in between the trials (2-3 minutes) in order to allow recovery to occur. This procedure ensured high subject reliability in that the instructions and conditions for all the tests were consistent in relation to the participants' information and their motivation [17].

Standing Long Jump

The Standing Long Jump (SLJ) test was carried out in an indoor gym to measure lower body explosive power. They completed three trials, and the average distance from all three jump trials was considered in the assessment. Before any of the tests participants were subjected to warm-up exercises to their muscles before undertaking the tests involving stretching exercises such as the dynamic stretches, and some plyometric exercises before any of the tests. The test was conducted on a non-slip surface to avoid any incidents with the liquid and for the best outcomes with the test. The subjects were required to get behind a defined line, with their feet a little apart in a v-shape. Before that, they had to take off and land using a two-foot carry-out, flailing their arms and bending their knees to leap forward as far as they could. The subject's jump distance was recorded using a measuring tape from the starting line to the nearest point of contact on the landing surface, which was the heel. To avoid undue fatigue and to allow the participant's muscles to rest adequate, rest intervals of approximately 2-3 minutes were availed between trials. The procedure implemented plans to keep the instructions and conditions equivalent over all the tests to maximize subject reliability and the participants' information and eagerness [18].

Countermovement Jump Test

A performance test of lower body explosive power, namely the Countermovement Jump (CMJ) test, was also performed in an indoor gym. All subjects attained three jumps from which the best value was used for analysis. Before the test, subjects also did the general warm-up that involved the dynamic stretches and plyometric movement to attenuate the possible muscle pulls. Before the test, a non-slip surface was provided to avoid any incidents and to obtain similar results across the test. All performers started off the performance erect with their feet aligned to the width of their shoulders. It required them to make a fast down swing in the knees and hips while at the same time, they had to immediately explode off the ground by pushing with the arms. Records of jump height were obtained either by the use of the jump mat or a vertical jump measurement apparatus. Breaks of about 2 - 3 minutes were awarded between each trial to allow the subject to be fully recovered. The procedure was designed to ensure the highest reliability of the subject with regard to the instructions and conditions of all tests given for participation, warranting the subject competence by properly informing and appealing to the subject motivation [19].

Change of Direction Speed

Agility, in this case, was measured by the change of direction speed by conducting an agility test in an indoor gym. There were three attempts, with the best performing time used in the assessment. Before actual testing, all individuals went through warm-up exercises comprising of stretches for rubbery muscles and some agilities to avoid the risk of strains. It was a test where the actual course was predetermined and along the trail, some obvious indicators determined turning patterns on the trail. The subjects ran through the course with as much speed as possible and had to turn at the marked points at 90 degree angles. The time for the runs was measured using a digital stopwatch to increase the level of accuracy during the tests. The test utilized a total of 4 cones. (5 yards = 4.57 m, 10 yards = 9.14 m). One and the same tester was giving the instructions and handling the stopwatch in order to avoid some inaccuracy. A mild warm-up was performed before the trials, and rest intervals of 2-3 minutes were allowed between trials to afford the subjects sufficient recovery time. The ICC with 95% CI for CODS time was 0.82 (0.80 – 0.92). The procedure was designed to get the highest degree of subject reliability by keeping instructions and environmental conditions constant to the optimum level so that the subject became well aware and motivated to perform the tests [20].

Statistical Analysis

Data analyses were done using a statistical analysis software known as SPSS and its version is 24. 0. 0 (IBM, New York, USA). Outcome variables are expressed as the mean and standard deviation. The assumption of normality and homoscedasticity of the data was checked by applying the Shapiro-Wilk test and Levene's test to compare variance, respectively [21]. Therefore, Analysis of Covariance (ANCOVA) with the baseline scores as covariate, was used to determine the specific effects of the training. The pairwise comparisons were carried out because the ANOVA test showed that the groups differed significantly from each other. In this study, post-hoc analyses were conducted to determine the specific differences between groups. These calculations using the formula: [(meanpost – meanpre) / meanpre] ×100 were performed using a customized Microsoft Excel sheet [22]. The post-hoc analyses were carried out to further elucidate the significant differences identified by the ANOVA. In line with the analyses for the independent samples t test, ES was calculated from the ANCOVA output as partial eta squared (ηp^2). Thus, Hedge's g was calculated to make comparisons on how the ES has changed between pre- and post-measurements within each group. According to [23], ηp^2 of measures was counted as small: less than 0. 06, moderate: between 0. 06 – 0. 13 and large: that was 0. 14 or more. The interobserver reliability of the measure was calculated as the intraclass correlation coefficient between Trial 1 and Trial 2, and interobserver reliability was considered to be poor if < 0. 5, moderate if 0. 5 – 0. 75, good if 0. 75 – 0. 90 and excellent if > 0. 90 [24]. Significance tests were based on p-values of ≤0. A logical analysis of the result revealed that the p-value of <005 was deemed statistically critical.

3. Results

Table 3 presents detailed results of the data analysis. The Shapiro-Wilk test results ($p > 0.05$) confirmed that all variables were normally distributed. The CST group exhibited positive training adaptations across all selected dependent variables, as follows: 15m sprint pre to post percentage changes (4.08%) with a delta of 0.04, 30m sprint pre to post percentage changes (1.56%) with a delta of 0.01, upper body strength pre to post percentage changes (6.87%) with a delta of 0.06, standing long jump pre to post percentage changes (4.66%) with a delta of 0.04, countermovement jump pre to post percentage changes (15.69%) with a delta of 0.15, and change of direction speed pre to post percentage changes (12.35%) with a delta of 0.12. The within-group improvements following the CST intervention ranged from small to very large magnitudes. Significant improvements were observed, with very large ES ($g > 1.15$) detected for SLJ ($g = 1.634$; $p = 0.001$), CMJ ($g = 7.110$; $p < 0.001$), and CODS ($g = 3.142$; $p = 0.001$). On the other hand, the control group did not exhibit any significant difference in any dependent variable at pre compared to post intervention. The ANCOVA analysis for the current study is shown in Table 3, which showed significant differences in all selected outcome measures at the post-test after twelve weeks, preferential for the CST group. Indeed, the eta-squared values derived from the ANCOVA analysis revealed that the size of the above differences was large ($\eta p^2 > 0.13$).

Table 3. Statistical Analyses Between Core Strength Training Group and Active Control Group on Bio-motor Fitness Variables Before and After Intervention

Bio-motor Fitness Variables	Core Strength Training Group (n=8)		Active Control Group (n=8)		ANCOVA (P-value)
	Pre-Test	Post-Test	Pre-Test	Post-Test	
	Mean (SD)		Mean (SD)		
15 m sprint (Sec)	2.69 (0.13)	2.58 (0.11) *	2.70 (0.12)	2.70 (0.14)	<0.005 LES
30 m sprint (Sec)	4.46 (0.18)	4.39 (0.17) *	4.45 (0.15)	4.46 (0.11)	<0.021 LES
UBS (m)	11.34 (0.14)	12.12 (0.18) *	10.54 (0.17)	11.13 (1.01)	<0.035 LES
SLJ (m)	2.36 (0.12)	2.47 (0.16) *	2.34 (0.09)	2.30 (0.21)	<0.001 LES
CMJ Height (cm)	37.40 (1.10)	43.27 (2.19) *	39.17 (3.2)	36.07 (4.3)	<0.001 LES
COD_s (Sec)	6.07 (0.16)	5.32 (0.27) *	5.66 (0.19)	6.20 (0.21)	<0.001 LES

Sec; Seconds, M; metre, UBS; upper body strength, SLJ; standing long jump, CMJ; countermovement jump, COD_s; change of direction speed

*pre to post significant difference, LES; large effect size

4. Discussion

Very short sprints, such as 15 and 30 meters, have been significantly improved in the group trained with core strength training compared to active control group. The core muscles, comprising the abdominals, lower back, and pelvic muscles, play a crucial role in maintaining stability and power transfer during sprinting. Enhanced core strength leads to better posture and alignment, allowing for more efficient force application during the initial explosive phase of a sprint. Research indicates that a strong core can reduce energy leakage and improve neuromuscular coordination, thus enhancing sprint performance [25]. The core acts as a stabilizer during high-intensity movements, allowing sprinters to maintain optimal biomechanics and reduce the risk of injury [26]. When the core is strong, athletes can generate more powerful hip and leg movements, which are critical in short-distance sprints where acceleration and speed are paramount [27]. Therefore, the integration of core strength training can provide a substantial advantage in short sprints by improving the speed and efficiency of muscle contractions necessary for rapid acceleration [28]. These improvements underscore the importance of core training in enhancing sprinting capabilities, particularly in the critical early phases of acceleration where maximal power output and speed are required.

The development of upper body strength in a group trained with core strength training, compared to an active control group found more, which is attributed to the core's critical role in overall body mechanics and force generation. Core strength training, which focuses on muscles in the trunk region, including the abdominals, obliques, lower back, and pelvis, enhances the stability and coordination needed for effective upper body movements. According to Behm et al. [29], a strong core acts as a stabilizer and force transducer, improving the efficiency and power of upper body exercises such as pushing, pulling, and lifting. This stabilization function reduces energy leaks during movement, allowing more force to be directed to the upper body musculature [30]. A study by Stanton et al. [31] demonstrated that participants who engaged in core stability exercises showed significant improvements in upper body strength tests, highlighting the interconnected nature of muscle groups. This phenomenon is further supported by a study by Willardson [27], which indicates that core strengthening exercises can enhance neuromuscular efficiency, leading to better recruitment and activation of upper body muscles during resistance training. Additionally, the core serves as a vital component in the kinetic chain, transferring energy between the lower and upper body. Enhanced core strength contributes to a more robust and stable base from which upper body muscles can generate greater force [26]. In contrast, an active control group engaging in non-specific training was inexperienced with the same degree of improvement in upper body strength, as their regimen might lack the targeted activation and strengthening of core muscles that underpin and enhance upper body performance. Thus, the substantial improvement in upper body strength observed in the core training group is largely attributed to the core's role in enhancing overall muscular efficiency, stability, and force generation capabilities, as corroborated by multiple studies within the exercise physiology domain.

The group that underwent core strength training demonstrated improved standing long jump performance in comparison to the active control group. This can be attributed to the increased lower body strength that arises from engaging core muscles and the subsequent effects on the kinetic chain [30]. Core strength training has been shown to improve the stability and power generation capabilities of the trunk muscles, which in turn facilitates more efficient force transfer from the lower extremities to the upper body during explosive movements like the standing long jump [26]. This improved force transfer is particularly relevant to lower body strength, as the core muscles play a crucial role in stabilizing the pelvis and spine during leg extension, allowing for greater power output from the hip, knee, and ankle joints [32]. Furthermore, many core exercises, such as planks, bridges, and rotational movements, require co-activation of leg muscles, particularly the quadriceps, hamstrings, and gluteal muscles, which contribute to overall lower body strength development [27]. Recent studies have demonstrated that integrated core training programs can lead to significant improvements in lower body strength measures, including squat strength and vertical jump performance [33]. The activation of leg muscles during core exercises, especially those involving anti-rotation and anti-extension principles, can lead to increased neural drive and motor unit recruitment in the lower extremities, potentially enhancing strength adaptations [34]. Additionally, the improved core stability resulting from targeted training may allow for more efficient and powerful hip extension during the jumping movement, as the pelvis provides a stable base for force production. The synergistic relationship between core and lower body muscles is further emphasized by the concept of the serape effect, which describes the diagonal force transmission from the lower body through the core to the upper extremities, highlighting the importance of a strong core in optimizing lower body power output [35]. Core training has been associated with improved balance and proprioception, which can contribute to enhanced neuromuscular control and force production capabilities in the lower limbs during dynamic movements like the standing long jump [36]. The cumulative effect of these adaptations resulting from core strength training can lead to significant improvements in lower body strength and power, ultimately manifesting in superior standing long jump performance compared to active control groups that may not receive the same integrated approach to strength development [37].

Core strength training has been shown to improve the stability and power generation capabilities of the trunk muscles, which in turn facilitates more efficient force transfer from the lower extremities to the upper body during explosive movements like the CMJ [26]. This improved force transfer is particularly relevant to lower body explosive strength, as the core muscles play a crucial role in stabilizing the pelvis and spine during rapid leg extension, allowing for greater power output from the hip, knee, and ankle joints [32]. The activation of leg muscles during core exercises, especially those involving anti-rotation and anti-extension principles, can lead to increased neural drive and motor unit recruitment in the lower extremities, potentially enhancing explosive strength adaptations [34]. Recent studies have demonstrated that integrated core training programs can lead to significant improvements in lower body explosive strength measures, including CMJ height and power output [38,39]. The improved core stability resulting from targeted training may allow for more efficient and powerful hip extension during the jumping movement, as the pelvis provides a stable base for rapid force production [40]. Core training has been associated with improved balance and proprioception, which can contribute to enhanced neuromuscular control and rate of force development in the lower limbs during dynamic movements like the CMJ [36]. The synergistic relationship between core and lower body muscles is further emphasized by the concept of the serape effect, which describes the diagonal force transmission from the lower body through the core to the upper extremities, highlighting the importance of a strong core in optimizing lower body power output [35]. Core strength training enhances the stretch-shortening cycle (SSC) utilization during the CMJ, as a stable core allows for more effective energy storage and release in the lower body muscles during the countermovement phase [41]. This improved SSC function can lead to greater power production and jump height in the CMJ [42]. Moreover, core training has been shown to improve postural control and trunk stability during dynamic movements, which may contribute to more efficient force production and transfer during the explosive phase of the CMJ [43]. The enhanced core strength and stability may also allow for better maintenance of optimal body positioning throughout the jump, leading to improved jump mechanics and performance [30]. Recent research has also suggested that core training can enhance intermuscular coordination between the trunk and lower extremities, potentially leading to more synchronized muscle activation patterns during explosive movements like the CMJ [44]. Furthermore, the improved core stability may contribute to reduced energy leakage during force transmission, allowing for more efficient power transfer from the lower body to the upper body during the jump [45]. The cumulative effect of these adaptations resulting from core strength training can lead to significant improvements in lower body explosive strength, ultimately manifesting in superior CMJ performance compared to active control groups that may not receive the same integrated approach to strength development [37,46].

Change of direction ability in the group trained with core strength training, compared to the active control group, is attributed to the enhanced neuromuscular control, stability, and power transfer facilitated by a stronger core [39]. Core strength training has been shown to improve the body's ability to rapidly generate and transfer force through the kinetic chain, which is crucial for quick and efficient changes in direction [47]. The core muscles play a vital role in maintaining postural control and balance during dynamic movements, allowing for more precise and rapid adjustments in body position during agility tasks [48]. Improved core stability contributes to better trunk control, which is essential for maintaining balance and redirecting momentum during sudden directional changes [49]. Additionally, core training enhances proprioception and body awareness, enabling athletes to more effectively sense and respond to changes in body position and movement demands. The integration of core muscles in multi-joint movements typical of agility drills leads to improved inter-muscular coordination, facilitating more efficient energy transfer between the upper and lower body [50]. Core strength training also contributes to enhanced eccentric strength, which is crucial for decelerating and changing direction quickly [51]. The improved core stability allows for better force absorption and redistribution during the deceleration phase of a change of direction, enabling athletes to transition more rapidly into the acceleration phase of the new direction [52]. A strong core provides a stable base for the lower extremities to generate force, potentially improving the rate of force development and power output during the propulsive phase of directional changes. The enhanced trunk control resulting from core training may also contribute to more efficient body lean and weight shifting during agility tasks, allowing for smoother and faster transitions between directions [53]. Ultimately, it manifests in superior performance compared to active control groups that may not receive the same integrated approach to core and lower body development [54,55].

5. Conclusions

In summary, the bio-motor fitness components of collegiate soccer players were significantly improved by the 12-week core strength training (CST) program, which included three sessions per week. The effectiveness of this training regimen in improving the physical performance of soccer athletes was demonstrated by the CST group, which exhibited significant improvements in the selected outcome parameters. In order to enhance training outcomes, future research should investigate the potential variations and long-term benefits of CST protocols.

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