The effect of complex contrast training~~complex and contrast training~~ with different training frequency on the physical performance of youth~~ng~~ soccer players: A randomized study

Complex ~~and~~ contrast training and performance of youth soccer players

Helder Barra de Moura[1,2], João Guilherme Vieira[2,3], Francisco Zacaron Werneck[4], Michal Wilk[5], Bruno Pascoalini[6], Victor Sabino de Queiros[7], Gilmara Gomes de Assis[8], Marta Bichowska[9], Jeferson Macedo Vianna[2,3], José Vilaça-Alves ~~José Manuel Vilaça Maio Alves~~[1]

1- Research Center in Sports Sciences, Health Sciences and Human Development (CIDESD), University of Trás-os-Montes and Alto Douro, 5001-801 Vila Real, Portugal.

2- Strength Training Research Laboratory, Federal University of Juiz de Fora (UFJF), 36036-900 Juiz de Fora-MG, Brazil.

3- Postgraduate Program in Physical Education, Federal University of Juiz de Fora (UFJF), 36036-900 Juiz de Fora-MG, Brazil.

4- Physical Education Department, Federal University of Ouro Preto (UFOP), 35400-000 Ouro Preto-MG, Brazil.

5- Institute of Sport Sciences, Jerzy Kukuczka Academy of Physical Education in Katowice, 40-065 Katowice, Poland.

6- Postgraduate Program in Rehabilitation Sciences and Physical-Functional performance, Federal University of Juiz de Fora (UFJF), 36038-330 Juiz de Fora-MG, Brazil.

7- Postgraduate Program in Health Sciences, Federal University of Rio Grande do Norte (UFRN), 59075-000 Natal-RN, Brazil.

8- Postgraduate Program in Integrative Physiology, Sao Paulo state University, 14801-385 Araraquara-SP, Brazil.

9- Faculty of Physical Education, Gdansk University of Physical Education and Sport, Gdansk, Poland.

Corresponding Author:
Helder Barra de Moura, MSc. Research Center in Sports Sciences, Health Sciences and Human Development (CIDESD), University of Trás-os-Montes and Alto Douro, 5001-801 Vila Real, Portugal. Phone: +55 32 99912-7070.

Email address: helderbarrademoura@gmail.com

Abstract

Background: Complex contrast training (CCT) methods are potentially an efficient method to improve physical abilities such as muscle strength, power, speed, and agility that are extremely important in developing soccer players of different age categories~~Physical abilities such as muscle strength, power, speed, and agility are extremely important in developing soccer players of different age categories. Complex-contrast training (CCT) methods are potentially efficient in improving these capacities, although there is still a lack of sufficient empirical evidence~~. **Aim:** This study aimed t~~T~~o analyze the effects of six weeks of CCT programs applied in different training frequency (sessions per week) on youth soccer players performance. **Methods:** Twenty-one youth soccer players (age: 15.3±1.1 years; body mass 64.9±0.7 kg; height 175.4±0.7 cm) were randomized into three groups: a regular pre-season training control

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group (G0, n=8), a group with regular pre-season training plus twice-a-week CCT (G2, n=6), and a group with regular pre-season training plus thrice-a-week CCT (G3, n=7). The CCT consisted of soccer skills-based exercises distributed across five stations, to be performed prior to regular practice during a 6-week pre-season period. The agility (505 Agility test), sprint (S5 and S15), jump (SJ and CMJ), and free kick speed (11 m from the goal) of the groups were analyzed pre and post the CCT intervention. The players underwent a 6-week pre-season period during which CCT was incorporated into their regular training sessions~~regular pre-season training as control (G0, n=8), and regular pre-season training plus 2 and 3 sessions of CCT per week (G2, n=6; e G3, n=7). The groups were evaluated for agility (505 Agility test), sprint (S5 and S15), jump (squat jump and countermovement jump), and free kick speed (11 meters from the goal). The CCT was introduced into the players regular training sessions as soccer skills-based exercises distributed in five stations, to be executed before regular practice during a 6-week pre-season period. Every two weeks, a 5% exercise load was adjusted accordingly~~. ~~Players were re-evaluated after the pre-season.~~ **Results:** A statistical difference was identified for timepoint for the players' CMJ ($p=0.023$; $\eta^2=0.343$) and the free kick speed ($p=0.013$; $\eta^2=0.383$) using ANOVA. The G3 presented a significant improvement in the CMJ ($p=0.001$) and the free kick speed ($p=0.003$) pre- to post-CCT~~A group x moment interaction was identified for the players Jump (CMJ) ($p=0.023$; $\eta^2=0.343$) and the free kick speed ($p=0.013$; $\eta^2=0.383$). The G3 presented a significant improvement in the CMJ ($p=0.001$) and the free kick speed ($p=0.003$) pre- to post-CCT~~. No other significant changes were observed in the players performance ($p>0.05$). **Conclusion:** The CCT training program with a weekly frequency of 3 days per week is effective in improving free kick speed and CMJ performance~~countermovement jumping ability~~ in youth male soccer players from U-15 and U-17 categories. Such training programs can fine-tune the athlete's preparation for competition. Nevertheless, other

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performance tests did not show significant improvements, refuting our hypothesis. Thus, further investigations are necessary to determine the efficacy of the CCT.

Keywords: Resistance Training, Soccer, Team Sports, Youth Sports.

Introduction

Muscle strength is recognized as an essential component for high performance in athletes of different sports during competition (Wisløff et al. 2004), especially in athletes at puberty (Malina et al. 2015). However, it is important to note that strength alone may not be the sole determinant of high performance. Stimulating muscle strength during ~~in association with~~ the biological maturation phase benefits~~can be helpful in training~~ youth athletes (Malina et al. 2015; McQuilliam et al. 2020), while~~.~~ e~~E~~vidence suggests that ~~motor abilities other than muscle strength such as~~ agility, speed, and power output are crucial for athletic performance (Cormier et al. 2020; Seitz et al. 2014); and resistance training (RT)~~ is effective~~ effectively enhances~~in enhancing~~ these abilities (Hammami et al. 2017; Maio Alves et al. 2010). RT is directly associated to improvements in specific sports drills (SSD) such as change of direction, acceleration, deceleration, sprints, jumps, and kicks (Paul et al. 2016; van den Tillaar & Marques 2009).

Considering this fact, two methods of combined training have emerged in the last decades: Complex training and Contrast training~~Considering this fact, two methods of combined training have emerged in the last decades: Complex training and Contrast training~~ (Cormier et al. 2020; Kumar et al. 2023; Maio Alves et al. 2010). Complex Training is a training approach that involves the completion of a heavy exercise followed by an explosive exercise, typically incorporating exercises at 80-90% of 1 repetition maximum (1RM), plyometric exercises, and strength-speed development (SSD) within the same training session~~Complex Training is defined as the combination training that includes exercises with 80-90% of 1 repetition maximum (1RM), plyometric exercises, and SSD in the same training session~~ (Ebben 2002; Freitas et al. 2017; Maio Alves et al. 2010; Mihalik et al. 2008). Conversely, Contrast Training is a combination training method that utilizes exercise sets of six repetitions with high loads (60-80% of 1RM), alternating with six repetitions of either low loads (30-50% of 1RM)

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or bodyweight, along with SSD~~Conversely, Contrast Training is defined as the combination training that involves the use of exercise sets of six repetitions with high loads (60-80% of 1RM), alternating with six repetitions of either low loads (30-50% of 1RM) or the bodyweight, and SSD~~ (Lagrange et al. 2020; Maio Alves et al. 2010; Smilios et al. 2005). The combination of exercises using high and low loads, as well as incorporating plyometric exercises and SSD, has shown potential to enhance athlete's performance in various sports~~Combination of exercises with high- and low-loads and those mimicking with plyometric exercise as well as SSD, may potentially improve athlete's performance in different sports~~ (Abade et al. 2020; Argus et al. 2012; Dodd & Alvar 2007; Maio Alves et al. 2010). Based on the positive effect on athletes' performance, a new training method called Complex Contrast Training (CCT) was conducted, which is a combination of two previously known methods.~~Based on this positive effect on athletes' performance, a new training method called complex contrast training (CCT) was conducted, which is a combination of two previously known methods (complex training and contrast training).~~

~~Either~~ Both complex or contrast training have demonstrated to utilize a the postactivation potentiation enhancement (PAPE) in the neuromuscular system of the muscles engaged ~~to~~ in the task. In training practice, the PAPE effect is achieved by using a conditioning activity (CA) with a relatively high, but submaximal external load (i.e., below 1RM), followed by an explosive postactivation exercise with a biomechanically similar movement pattern (Seitz & Haff 2016). This refers to a potential enhancement ~~in the~~of synaptic conduction and number of recruited motor units, that results in an ~~increasing~~ increased ~~the~~ rate of force development (RFD) and power output required in a specific sport skill, caused by ~~a~~ the CA (Docherty & Hodgson 2007; Freitas et al. 2017; Lagrange et al. 2020). ~~So~~Considering the above, a the positive relation between RFD and sports skills suggests that PAPE might improve performance in sports in which explosive skills are demanded (Gołaś et al. 2017; Kilduff et al. 2007).

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Moreover, it is important to consider the time-dependence of PAPE. The interval between the CA and subsequent explosive activities is crucial for maximizing its effect. The optimal interval duration for inducing the desired PAPE response is still being investigated, with studies exploring a range of intervals from 0 to 21 minutes

Furthermore, CCT has been extensively investigated with regard to training variables (Cormier et al. 2020), with training frequency being an important variable that requires further investigation ~~regarding the application of CCT~~. Recently, Kumar et al. (2023) showed that CCT with different weekly frequency (2 vs. 3) and equalized volume-load provided similar effects on measures of physical fitness in active adult males. However, an athlete's goal is to improve their score on the modified agility T-test, CCT with a weekly frequency of 3 days elicits greater improvements compared to CCT with a weekly frequency of 2 days. found that CCT led to better performance in S5, S15 and SJ, but the number of CCT sessions per week (1 vs. 2) did not affect the performance of these skills. Brito et al. (2014), reported no significant differences in sprint and agility performances after nine weeks of complex training with a frequency of two sessions per week. However, Hammami et al. (2017), found significant improvements in many important components of athletic performance relative to standard in-season training (e.g. sprint and agility) of youth athletes (~16 years old) after eight weeks of contrast training with a frequency of two sessions per week. Such inconsistency in the scientific findings might be due to a high heterogenicity throughout the study's methods with regard to populations' age, exercises, training frequency, and other variables of comparison.

~~Regarding the above mentioned, t~~The aim of the present study was to analyze the effects of six weeks of CCT programs applied in different training frequency (sessions per week) on youth soccer players performance. For that purpose, we compared soccer players speed, agility, jumping ability and free kick speed in regular training vs. CCT 2 and 3 times per week during the pre-season. We hypothesized that the incorporation of CCT training into regular football

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training sessions would increase the athltes physical performance~~ of individual athletes~~. Furthermore, we expected~~assumed~~ that the degree of performance improvement would be independent of the number of CCT training units performed in a weekly microcycle.

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Materials & Methods

Experimental approach to the problem

This study was conducted during a 12-week pre-season training period. The soccer players were randomly assigned into two experimental groups with different volume of CCT in addition to their regular training routines, and one control group. Within- and between-factors were assessed to compare the effects of different CCT frequency on the players' sprint, agility, vertical jump, and free-kick speed. The study was conducted as: week-1; presentation of methods, week-2-3; familiarization with the CCT protocol, week-4; 1RM evaluation, week-5; performance tests, week-6-12; CCT program intervention, week-13; performance tests. Participants were instructed not to consume food or drinks with caffeine or engage in any vigorous activity other than those of the training program, during the experiment (Figure 1).

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Figure 1. Experimental design of the study.

Participants

Twenty-one soccer players (age:15.3 ± 1.1 years, body mass: 64.9 ± 0.7 kg, height: 175.4 ± 0.7 cm), participating in the Minas Gerais state Championships - Brazil (U-15 and U-17 categories) were randomly assigned to three groups: 2 CCT sessions per week (n:6; G2), 3 CCT sessions per week (n:7; G3), and regular training as control (n:8; G0). The CCT sessions were embodied to the regular training program. A simple randomization was conducted by an outer researcher using Microsoft excel 365 for Windows (Microsoft Corporation, Redmond, Washington, USA), after pre-intervention evaluations.

Inclusion criteria

The participants were classified as post- pubescent (adolescent) according to Tanner's scale (Tanner 1986) and current medical clearance for the training protocols and research were granted. Exclusion criteria were applied to ensure the validity of the motor performance assessment, and no participants were excluded due to the use of ergogenic substances, illnesses, pain indicators, or injuries during the experiment. Players in the U-17 category had limited previous experience in RT, with a maximum of 1 year training, while players in the U15 category had no previous experience in RT~~Participants that used ergogenic substances that could interfere in the evaluation of motor performance, were ill, indicated pain or injuries during the experiment were excluded from the analyses~~. All research protocols agreed with the Declaration of Helsinki (2013) (Association 2013) and approved by the Ethical Committee of the Federal University of Juiz de For a - Minas Gerais - Brazil (CEP: 37256314.4.0000.5147/2016). In addition, all parents of the athletes signed a assent form and all participants signed an informed consent prior to data collection.

Anthropometric measurements

The participants height and body weight were measured by a stadiometer (Sanny®, São Paulo, Brazil) and a mechanical scale (Filizola®, São Paulo, Brazil), while body composition was determined by focal ultrasonography (Body Metrix, São Paulo, Brazil) of mamillary thorax, midaxillary, triceps, subscapular, abdominal, suprailia and thigh skinfolds. Body density was estimated by the Jackson & Pollock (1978) protocol and percentage of body fat was then calculated using the following formula: $\frac{\mathbf{4,95}}{\textbf{densidade corporal}} \mathbf{- 4,5 \times 100}$ (Siri 1993). All measurements were performed by a single examiner.

Performance tests

The assessment included the one-repetition maximum (1RM) test on the participants' dominant side for the hip flexion exercise. Furthermore, all other 1RM tests, such as leg extension, squat (guided bar), hip adduction (chair), and seated calf raise, were performed without specific consideration for the dominant side. These exercises were conducted using equipment from the same brand (Strong Machine, Minas Gerais, Brazil).~~The *one-repetition maximum* (1RM) test was applied to the players dominant side on the exercises: squat (guided bar), seated calf raise, leg extension, hip adduction (chair), hip flexion.~~ The evaluation followed the recommendations of the National Strength & Conditioning Association (NSCA 2016). A 3-week familiarization period prior to the field tests was introduced to the participants and all tests were performed on a soccer field (grass range 25-30mm). Jumping ability was evaluated at the Strength Training Research Laboratory.

The players agility~~*Agility:*~~ was evaluated using the 505 Agility test by Sheppard & Young (2006) and the photocells Speed Test Fit (Cefise, São Paulo, Brazil). This test evaluated the ability to change direction while in motion.

Sprinting speed~~*Sprinting speed*~~ was evaluated at a distance of 15m with photocells (Speed Test Fit Cefise, São Paulo, Brazil) positioned at 0,5 and 15m. Participants were instructed to start their sprint with their foot placement positioned behind the first photocell. The timing was triggered by the interruption of the light beam when the participants crossed the first photocell. This method follows the protocol described by Bosco et al. (1983)~~Participants were instructed to sprint as fast as possible across the photocells according to Bosco et al. (1983) protocol~~. The best time out of 3 sprints was registered.

Jumping ability was evaluated using two different tests: the Squat Jump (SJ) and the Countermovement Jump (CMJ). For the SJ, participants started from a squat position with knees at a 90º angle, which was established using a goniometer (Staline®, USA). In the CMJ, participants jumped from an upright position without using their arms. Both jumps were performed on a force plate (Cefise, São Paulo, Brazil) with a resolution of < 0.5 kg (5N), and the peak jump height (cm) was recorded at a sampling rate of 600 Hz using the Vertical Jump Power software (Cefise, São Paulo, Brazil). Each participant performed three attempts for both tests, and the best jump height achieved was recorded~~*Jumping ability* was evaluated by 2 tests: the Squat jump (SJ), in which participants would start from a squat position with knees at a 90º angle established by a goniometer (Staline®, USA); and a Countermovement jump (CMJ), in which participants would jump from upright position without using their arms. The jumps were performed on a force platform (Cefise, São Paulo, Brazil) with < 0,5Kg (5N) resolution and peak jump height (cm) recorded at 600 Hz by the software Vertical Jump Power (Cefise, São Paulo, Brazil). The best jump out of 3 attempts was registered~~.

Free kick speed ~~*Free kick speed*~~ evaluation was performed according to the Sousa et al. (2003) protocol. A soccer ball (weight 410-450g, pressure 600-1100g/cm^{2}j - Penalty, São Paulo, Brazil) was placed on the grass, 11 meters from the goal, and a Radar Gun~~Police Radar~~ (Stalker, Texas, USA) was positioned behind the ball for measurement of instant speed (0.013 m/s error). The participants performed two free kicks with a 2-min rest interval in between. The highest ball speed was registered.

Complex Contrast Training~~*Complex and Contrast Training (CCT)*~~

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The G2 and G3 had the CCT inserted to the beginning of their training routines (after warm-up) in 2 sessions per week or 3 sessions per week, respectively. A specific warm-up was also included for these subjects' preparation to CCT, and the CCT sessions were organized as five exercises' stations including with a general exercise, a multiform exercise, and a specific exercise as follows (Figure 2):

Station 1 - 6 repetitions of Squat (80% of 1RM) + 5-m-high skipping + 5-m sprint.

Stations 2 - 6 repetitions of seated calf raise (90% of 1RM) + 6 ~~Jump~~ jumps + 3 jump headers.

Station 3 - 6 repetitions of knee extensions (80% of 1RM) + 6 jumps from a 60-cm bench (FIJU7944, São Paulo, Brazil) to floor + 3 x jump header from the bench.

Station 4 - 6 repetitions of hip adductions on a chair (80% of 1RM) + 6 jumping jacks + 5-m change of direction.

Station 5 - 6 repetitions of unilateral hip flexion (85% of 1RM) + 6 kicking simulations + 3, 11-m free kicks.

After every 2 weeks of CCT training, 5% of the 1RM load was added.

###Insert figure 2 near here###

Figure 2. Complex and Contrast training.

Statistical analyses

Gaussian distribution and homogeneity were verified by Shapiro-Wilk's and Levene's test, respectively, and presented in mean and standard deviation. Categoric variables were presented in relative and absolute frequencies. Two-way mixed ANOVA was used to compare the effect of the two CCT protocols (between factors - 3 groups, and within factors - 2 time points~~2 times~~). One-way ANOVA were~~was~~ used for age comparison. Sphericity of data was evaluated by Mauchly's test, and the degrees of freedom were adjusted using Greenhouse-Geisser correction. Main effects and/or significant interactions were analyzed by multiple comparisons, with Sidak's post hoc. To test for differences in the proportion of maturational stages in each group, the Fisher's Exact test was used, by means of cross tables. Effect size was calculated by eta squared (η^2), with the magnitude considered as: small - $\eta^2 = 0.01$; moderate - $\eta^2 = 0.06$; and large - $\eta^2 = 0.15$ (Cohen 1988). All analyses were performed in the statistical software SPSS version 27.0 (IBM corp., Armonk, NY, USA) and the figures created in GraphPad software (Prism 8.0.1, San Diego, CA, USA), adopted a significance level of 5%.

Results

Twenty-one players completed the study (G0=8; G2=6; and G3=7). No differences in time point~~in moment~~ vs group were found for body mass [$F_{(2,18)}$=0.988; p=0.392; η^2=0.099], height [$F_{(2,18)}$=0.158; p=0.855; η^2=0.017], BMI [$F_{(2,18)}$=1.184; p=0.329; η^2=0.116], and percentage of body fat [$F_{(2,18)}$=1.882; p=0.181 η^2=0.173]; or between the groups age [$F_{(2,18)}$=0.305; p=0.741], body mass [$F_{(2,18)}$=0.065; p=0.938], weight [$F_{(2,18)}$=0.861; p=0.439], BMI [$F_{(2,18)}$=0.230; p=0.797], and percentage of body fat [$F_{(2,18)}$=1.418; p=0.268]. Fourteen participants (67%) were at maturational stage 4 in Tanner's scale (Tanner 1986). Fisher's test did not identify a significant difference in participants maturational stages (p=0.480). Participants characteristics are presented in Table 1.

###Insert table 1 near here###

Table 1. Anthropometric characteristics and effect sizes.

No group x time point~~time × group~~ interaction was found for S5 [$F_{(2,18)}$=0.058; p=0.944; η^2=0.06], S15 [$F_{(2,18}$ =0.732; p=0.495; η^2=0.075], agility [$F_{(2,18)}$=0.684; p=0.517; η^2=0.071] and SJ [$F_{(2,18)}$=1.544; p=0.241; η^2=0.146]. For the CMJ [$F_{(2,18)}$=4.701; p=0.023; η^2=0.343] and the free kick [$F_{(2,18)}$=5.598; p=0.013; η^2=0.383], a significant group x time point~~time x group~~ interaction was found. Pre- and post-CCT analyses revealed a statistically significant improvement, only in G3, for the CMJ (p=0.001) and the free kick speed (p=0.003) (Figure 3).

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Figure 3. Results of control group (G0) and experimental groups (G2 and G3) pre- and post-CCT.

G1 - control group; G2 - experimental group (2x/week); G3 - experimental group (3x/week); S5 - 5 meters sprint; S15 - 15 meters sprint; SJ - squat jump; CMJ - countermovement jump; pre - before intervetion; post - after intervetion; s - seconds; cm - centimeters; km h^{-1} - kilometers per hour; * Significantly difference compared with pre.

No significant differences in S5, S15, agility, SJ, CMJ and free kick speed was found between the groups (p>0.05). Table 2 shows the difference in the means (95% confidence interval) and Sidak's post-hoc values for the mentioned variables.

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Table 2. Between groups comparison.

Discussion

The main finding of the study is that CCT training, but only when three training sessions were performed (in addition to regular soccer training), resulted in a significant improvement in the youth soccer players performance. Significant improvements were observed in in CMJ and free kick speed. This demonstrates that improvements in players physical abilities following CCT require a minimum amount of training frequency ~~sessions~~ (volume). ~~That implies that, in well trained athletes, improvements in performance require a more skill specific approach for the exercises that seem effective in a dose-dependent manner.~~This implies that, in case of well-trained athletes, further enhancements in performance may require a more skill-specific approach and exercises that exhibit a dose-dependent effectiveness.

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The significant increase in CMJ and free kick speed performance observed exclusively in~~obtained only by~~ players who practiced CCT three times a week may be attributed due to a chronic enhancement ~~an enhancement~~ in the neuromotor recruitment of muscle fibers and calcium release by the sarcoplasmic reticulum (Tillin & Bishop 2009). ~~,~~These findings suggest that a high stimulation frequency is indispensable for eliciting substantial improvements in physical performance. Previous studies utilizing training protocols of 2-3 sessions per week have demonstrated improvements in athletes' CMJ results. However, these improvements were observed for periods longer than 6 weeks~~and a high stimulation frequency seems indispensable. Improvements in athletes CMJ result have been demonstrated in previous studies where was used training protocols of 2-3 sessions per week, however for periods longer than 6 weeks period~~ (Cormier et al. 2020; Kotzamanidis et al. 2005; Sáez de Villarreal et al. 2015; Tricoli et al. 2005). It seems that significant improvements in performance of youth soccer players require a frequency of at least 3 sessions of CCT per week, or else a longer CCT intervention period (Kotzamanidis et al. 2005; Maio Alves et al. 2010). Nevertheless, in this study we have demonstrated that a 6-week CCT protocol is effective in improving CMJ~~essential skills~~ in youth male soccer players from U-15 and U-17 categories, which shows to be a feasible strategy for pre-season preparations.

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The improvement in the free kick speed (p=0.003; Δ = 8%) in the -group that performed three CCT training sessions per week was consistent with a previous study that observed improvements in the physical fitness ~~and physical abilities~~ of young soccer players, particularly in increasing free kick efficiency~~.~~ (Cavaco et al. 2014). These improvements could be attributed to mechanisms such as improved motoneuron firing rate, increased neural coordination, and the positive transfer of muscle demands through the implementation of complex training~~Studies applying only RT in athletes have failed to demonstrate a transference of strength and power gains to functional skills~~ (Cronin et al. 2001; Robbins 2005. However, it is important to note that

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studies applying only resistance training (RT) in athletes (Aagaard et al. 1993; Trolle et al. 1993). In contrast with the findings of Cavaco et al. (2014), where ~~in which~~ an improvement in athletes' free kick efficiency was found after an 6-week training program with 2 sessions per week; in the present study, the group ~~group~~ which included ~~performed~~ two CCT training sessions per week the did not show such an improvement. This difference in outcomes may be attributed to variations in the protocols used, such as the specific training method employed and the number of stations utilized ~~was probably due to a difference in the protocols. For example,~~ Cavaco et al. (2014), -which could have impacted the results differently. Before the pre-season period, all athletes underwent a two-week familiarization phase with TR, followed by six weeks of CCT alongside regular soccer training for the experimental groups. The control group continued with RT alongside their regular soccer training. It is worth noting that there was no sudden increase in training loads during the pre-season period, which could explain the observed improvements. The training programs were designed to ensure consistency and controlled progress throughout the study.~~used one training method (Complex training) and only two stations, aspects that differ from the present study and may have impacted differently on our results~~.

We observed no significant changes in SJ performance among any of the studied groups following the training intervention. When comparing our study to previous studies on CCT,~~We did not find any significant change in SJ performance in any subject group after training. When comparing our study with previous studies addressing CCT,~~ Maio Alves et al. (2010) implemented an 8-week protocol comprising 2 weeks of RT adaptation followed by a 6-week CCT. They reported improvements in SJ performance that were independent of the training frequency (1 vs. 2 times per week). In another experiment,~~applied a 8-week long protocol with 2 weeks of adaption to RT plus a 6-week CCT. They registered gains in SJ performance that were independent of the training frequency (1 vs. 2 times per week). In a different experiment,~~

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Kotzamanidis et al. (2005) observed changes in SJ only after 13 weeks of the protocol (4 weeks of RT adaptation plus 9 weeks of intervention, 2 times a week). These findings support the notion that combining resistance and speed training in the same session is more effective than a conventional resistance program alone for enhancing running speed and jumping ability. The observed improvements in SJ performance may be attributed to neuronal factors or the optimal transfer of strength gains to running performance. Interestingly,~~observed changes in SJ only within 13 weeks of the protocol (4 weeks of RT adaption plus 9 weeks of intervention, 2 times a week). Curiously,~~ Taiana et al. (1991) implemented a training program similar to ours but did not observe any changes in SJ results. These conflicting results may be attributed to different mechanisms.~~applied a training program similar to ours and also and did not find any changes in SJ results. Perhaps the explanation for these conflicting results is the learning effect.~~ Bobbert & Van Soest (1994) reported that after resistance training, the nervous system must learn to control and transfer the additional force obtained to enhance vertical jump performance. This could potentially explain the absence of improvement in SJ observed in our study. Additionally, Cormier et al. (2020), emphasized that the level of the athlete and rest intervals in CCT protocols can influence outcomes. Elite and subelite team sport athletes demonstrated significantly greater enhancements in SJ height compared to amateurs, possibly due to their fatigue resistance and ability to induce PAPE. Training overload also plays a role, with the development of SJ depending on the frequency of resistance training sessions per week (Hoffman et al. 1990) . Although our study varied the training frequency (2 vs. 3 times per week), it is possible that the applied training volume was insufficient to generate significant improvements in SJ. Furthermore, previous studies (Baker 1996; Fatouros et al. 2000) have shown that combining resistance training with running performance, which involves intense stretch-shortening cycle movements, has a positive impact on SJ. Despite including speed performance in one of the stations, we did not observe any improvements. Regarding drop jump results, it is well known

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that this performance is mainly dependent on muscle stiffness (Young et al. 1999), which is increased by resistance training (Kubo et al. 2002). The lack of increase in SJ performance in our program could be attributed to insufficient adaptations in the muscle-tendon unit. These adaptations could be attributed to either neuronal factors or the optimal transfer of strength gains to running performance. Taking these findings into consideration, the lack of significant changes in SJ performance in our study may be influenced by factors such as the learning effect, training frequency, and rest intervals employed.~~reported that after resistance training the nervous system must learn to control and transfer the additional obtained force to increase the vertical jump.~~

The present study revealed no significant improvement in agility levels after 6 weeks of CCT training when compared to the group that did not undergo CCT, aligning with previous findings ~~The results regarding the change in the level of agility after 6 weeks of CCT training did not show a significant improvement compared to the group not performed CCT. A lack of changes in the athletes agility after CCT observed in the present study was also found in other studies~~ (Maio Alves et al. 2010; Tricoli et al. 2005). Despite incorporating recommended exercises that simulate directional changes in agility tests~~Even though we have followed~~ Maio Alves et al. (2010), the complexity of agility tasks suggests that motor control factors have a greater impact on agility performance than muscle strength or power capacity (Tricoli et al. 2005). –In contrast,~~recommendations and included exercises with a change of directions mimicking those present in the agility tests. Conversely,~~ García-Pinillos et al. (2014) observed improvements in agility among young soccer players after a 12-week CCT protocol, without concurrent changes in body composition. Their study emphasized the influence of various factors such as training status, age, gender, testing methods, and program characteristics on agility outcomes. However, comparing agility gains across studies is challenging due to the diversity of evaluation methods used. Considering the complexity of agility tasks and the

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interplay of factors like age, training status, and testing methods, designing tailored training programs that account for individual characteristics becomes crucial for optimizing agility enhancement. Further research is warranted to explore effective strategies for improving agility in diverse populations.~~did find changes in the agility of young soccer players induced by a 12-week CCT protocol, and without changes in body composition. However, it is impracticable to compare gains in agility reported by different studies considering the diversity of evaluation methods. In line with the results of the present study, Tricoli et al. (2005) state that agility tasks involve a higher complexity, therefore, are more influenced by motor control than by strength and power abilities.~~

Considering numerous previous studies (Brito et al. 2014; Hammami et al. 2017; Kotzamanidis et al. 2005; Maio Alves et al. 2010), in our experiment , we did not observe significant changes in sprint performances (S5 and S15) in any of the groups. In the Brito et al. (2014) study, the authors observed an improvement in the S20 sprint within 9 weeks of CCT. However, the training program used by Brito et al. [23] was three weeks ~~more prolonged~~longer when compared to the present study. Furthermore, Maio Alves et al. (2010) found significant reductions in sprint performances (S5 and S15), but the participants in the study by Maio Alves et al. (2010) had an average age of 17.4 years which is higher than the average age (15.3) of the participants in the present study. During maturational stage 5 (post-PHV), athletes will experience an increase in testosterone and growth hormones, which leads to improved muscle strength (Costa et al. 2021; Till et al. 2014) and peak velocity (Fernández-Galván et al. 2022).

In our study, consistent with numerous previous studies (Brito et al. 2014; Hammami et al. 2017; Kotzamanidis et al. 2005; Maio Alves et al. 2010), we did not observe significant changes in sprint performances (S5 and S15) among any of the groups. reported Brito et al. (2014) an improvement in the S20 sprint after 9 weeks of CCT, but their training program was three weeks longer than ours. Similarly Maio Alves et al. (2010), found significant reductions

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in sprint performances (S5 and S15), but their participants had a higher average age (17.4 years) compared to our study (average age of 15.3 years). Furthermore~~Similar to our results~~, Cavaco et al. (2014) also did not find changes in S15 sprint performance after 8 weeks of training (6 weeks of CCT) in youth athletes. Notably, their study had similar age and protocol duration as ours, while the mentioned studies involved populations above 16 years old. Therefore, the fact that 67% of our sample consisted of youth soccer players in maturational stage 4 (according to the Tanner scale) suggests that neuromuscular maturation may play a role in sprint performance improvements. Factors such as neural function, muscle stiffness, testosterone concentration, and muscle strength can influence the impact of maturational stage on performance (Costa et al. 2021; Mendez-Villanueva et al. 2011). ~~did not find changes in the S15 sprint performance after 8 weeks of training (6 weeks of CCT) in youth athletes. A deeper look through the data revealed that only this study involved subjects with age and time-exposure to the protocol that were similar to ours. Whereas the above mentioned studies used subsets of populations above 16 years old. Therefore, the fact that our sample was composed of 67% of youth soccer players in maturational stage 4 (Tanner scale (Tanner 1986)) suggests that the neuromuscular maturation might be putative for improvements in sprint performance (Myers et al. 2017). The impact of the maturational stage on performance can be attributed to several factors, including neural function, muscle stiffness, testosterone concentration, and muscle strength (Costa et al. 2021; Mendez-Villanueva et al. 2011).~~ Fernández-Galván et al. (2022) propose that lower sprinting performance in youth athletes at maturation stage 4 could be attributed to a decrease in relative strength due to increased body mass and height, as previously reported~~suggest that a possible reason for youth athletes in maturation stage 4 experiencing lower sprinting performance is the decrease in relative strength caused by increased body mass and height, as previously reported~~ (Comfort et al. 2014). Another possible explanation is that young athletes in maturational stage 4 may experience a phase of "motor clumsiness" as their motor

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coordination is disrupted by trunk and limb growth. These factors highlight the potential influence of maturational stage on sprint performance~~Another possible explanation is that young athletes at maturational stage 4 are going through the "motor clumsiness" phase when the athlete's motor coordination is disrupted by trunk and limb growth~~.

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A limitation of our study is that the CCT protocol was applied during the pre-season, which may introduce potential methodological conflicts. Furthermore, should consider prioritizing CCT interventions during the preparatory season and possibly dividing the players by position (e.g., defenders, forwards, and midfielders). Another limitation is the sample size, as our study included a limited number of 21 players, which may restrict the generalizability of the findings. Additionally, we did not perform a sample size calculation to determine the appropriate number of participants. We emphasize, the fact that we do not have the 1RM values of the players per group. PAPE also depends on training background and strength/power levels. Therefore, future research should aim to include larger and more diverse samples to enhance the external validity of the results~~A limitation of our study is that the CCT protocol was applied at the pre-season what creates a potential methodological conflict. Future studies should prioritize CCT protocol interventions at the preparatory season, and perhaps divide the players by position (e.g., defenders, forwards, and midfielders)~~.

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Conclusions

The CCT implementation to regular soccer training for youth athletes, in a regime of 3 sessions per week for 6 weeks, ~~showed~~ was effective in improving the athlete's CMJ~~jumping ability~~ and free kick speed. While further research is needed to explore optimal training protocols for enhancing other abilities such as agility and sprint performance, it is important to consider that factors beyond training volume, such as maturational stage, which may play a role in reducing the dose-response and frequency, while increasing the effectiveness of the intervention~~A~~

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~~greater volume of CCT sessions shall be necessary for provoking changes in other abilities such as agility and sprint performance~~.

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