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Original research papers

EFFECTS OF SIX-WEEK PRE-SEASON COMPLEX CONTRAST TRAINING INTERVENTION ON MALE SOCCER PLAYERS' ATHLETIC PERFORMANCE

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Abstract
Introduction. This study aimed to investigate the effects of a six-week complex contrast training (CCT) intervention on the athletic performance of highly-trained amateur male soccer players during the pre-season period. ***Material and Methods.*** Participants aged 21.3 were randomized to CCT (n = 7) or active (i.e. standard soccer training) control (CG; n = 9) groups. Athletic performance was assessed using the 30 m linear sprint test time, standing long jump distance (SLJ), countermovement jump (CMJ) height, and unilateral right-left knee flexion and extension isokinetic maximal strength tests. The experimental group replaced part of the standard soccer training schedule with three CCT sessions per week for six weeks. A two (pre-post intervention) by two (CCT, CG) mixed ANOVA was used to analyze the exercise-specific effects. In addition, between-group comparisons at post-test were conducted with baseline scores as covariate. Within group changes were analyzed using paired t-test. ***Results.*** Significant group-by-time interaction effects were found for all dependent variables ($p < 0.001 – 0.004$). Post-hoc tests using paired t-test revealed significant improvements in all dependent variables in CCT (all $p \leq 0.001$; effect size (g) = 0.29 – 0.96; %Δ = 4.5 – 14.7), but not in CG (p = 0.174 – 0.633; g = 0.03 – 0.20; %Δ = 0.4 – 2.6). Further, Bonferroni adjusted post-hoc analysis using baseline scores as a covariate showed post-test differences in favor of CCT compared to CG for all variables. ***Conclusions.*** CCT is recommended as an effective training strategy during the pre-season to improve athletic performance among highly-trained amateur male soccer players.

Key words: plyometric exercise, human physical conditioning, resistance training, muscle strength, soccer, athletic performance

Introduction

Soccer is a sport that requires short-duration maximal to near-maximal high-intensity efforts (e.g., sprints, jumps) at regular intervals [1, 2]. Moreover, such high-intensity efforts are crucial to overcome opponents and determine a player's performance potential during soccer games and tournaments [1, 3]. Indeed, the observation of such demands during training sessions may predict match outcomes [4]. These maximal to near-maximal efforts are positively associated with the strength/power of lower limbs [5, 6, 7, 8].

Different training methods are suggested for developing the strength/power of soccer athletes, amongst which heavy-load resistance training and plyometric training are among the most studied [9, 10, 11]. Both methods possess different characteristics, as heavy-load resistance training is more strength-focused while plyometric training is more velocity-focused [12]. However, similar benefits (with varying magnitude) are offered by both training methods through improving maximal strength, explosive strength (e.g., rate of force development), neural (e.g., motor unit activation/recruitment, synchronization), morphological (e.g., cross-sectional area), cellular and metabolic adaptations (e.g., muscle fiber type size and composition) [9, 13, 14, 15]. These adaptations underpin athletic performance developments deemed necessary for soccer preparedness (e.g., sprinting speed, jump, maximal strength) while reducing injury occurrence [16].

However, compared to a single training mode (i.e., resistance training or plyometrics), a combination of resistance and plyometric exercises (i.e., complex contrast training [CCT]) may further improve soccer players' performance [17, 18]. The CCT involves the performance of a biomechanically similar high-load low-speed resistance training exercise and low-load high-speed plyometric/ballistic exercise in a set-by-set format i.e., heavy resistance exercise followed by the immediate performance of low-load exercise [19]. Such a combination of exercises may help target both the force and velocity components and therefore optimize the force-velocity relationship curve [12], a key biomechanical factor in soccer players during the pre-season [20]. Additionally, the sequencing of heavy-load and low-load exercises in such a format also stimulates the post-activation potentiation (~28 sec) and thus post-activation performance enhancement of the latter low-load exercise [12, 21], by increasing motor unit recruitment and force-production potential of the used musculature, thereby further enhancing the neuromuscular adaptations [21, 22]. Another benefit of CCT is that it provides a time-efficient combination of traditional resistance and plyometric exercise into a single session, which may assist strength and conditioning coaches in overcoming congested weekly micro-cycles [11, 23, 24].

A recent survey study by Weldon et al. [11] on the practices of strength and conditioning coaches in professional soccer found the most common application (52%) of plyometric training was in the form of CCT when compared to other formats (e.g., before weights, separate days, after weights). Indeed, in the last decade a considerable number of studies have analyzed the effects of CCT on soccer players' athletic performance, recently summarized in two meta-analyses [17, 18]. In the first meta-analysis, Thapa et al. [17] reported CCT to be an effective strategy in improving soccer players' sprint, jump, and change of direction ability. Whereas the second meta-analysis [18] by the same group reported CCT to be effective in improving the maximal strength of soccer players, with positive trends shown towards improving aerobic endurance and repeated sprint ability. However, in the aforementioned meta-analyses [17, 18] only two of the included studies [25, 26] focused on the pre-season period. Miranda et al. [26] reported improvement in linear sprint, vertical jumps (i.e., squat jumps, countermovement jumps [CMJ]), maximal leg strength (i.e., one repetition maximum [1 RM] back squat), Yo-Yo intermittent recovery level 1, but not in change of direction ability (i.e., Illinois agility test) after four weeks of CCT among soccer players aged 17.3 competing at the national level. Whereas Maio Alves et al. [25] reported improvement in linear sprint and squat jump but not in CMJ and change of direction ability (i.e., 505 agility test) after six weeks of CCT among highly-trained soccer players aged 17.4.

In addition to the lack of studies in soccer groups other than male youths, previous studies have used one or two weekly sessions during the pre-season [25, 26]. However, no studies have investigated the effects of three weekly sessions of CCT during the pre-season. Indeed, there are several theoretical advantages of increased training frequency. For example, higher training frequency may provide more time with the net protein balance, thus enhancing muscular adaptations [27]. Similarly, greater weekly plyometric training frequency was reported to have favored bone mass accretion [28]. Furthermore, distributing the weekly load across higher frequencies (i.e., several days) may reduce fatigue during training sessions [27] and recovery duration between sessions [29]. Lastly, more frequent neuromuscular stimuli during a weekly training schedule may optimize motor learning [30].

Therefore, this study aimed to investigate the effects of six weeks of CCT with three weekly sessions on 30 m linear sprint, standing long jump (SLJ), CMJ with arm swing (CMJA), and peak torque of both legs during unilateral isokinetic knee extension and flexion, in highly trained amateur male soccer players during the pre-season. Based on previous evidence [17, 18, 24, 31], it was hypothesized that CCT would induce improvement in the athletic performance compared to an active control group (i.e., standard soccer training).

Material and Methods

Participants

The required sample size to conduct the study was estimated using statistical software (G*power; University 130 of Düsseldorf, Düsseldorf, Germany). The following variables were included in the a priori power analysis: study design, two groups, two measurements, alpha error <0.05, nonsphericity correction =1, correlation between repeated measures = 0.5, desired power (1-ß error) = 0.80, effect size (f) of 0.58 based on a previous study that investigated the effects of six-week CCT in amateur soccer players of similar age group on CMJ [32].

The results of the a priori power analysis indicated that a minimum of 5 participants would be needed for each group to achieve statistical significance for the main outcome of the study i.e., CMJA performance. The CMJA was chosen as the main outcome for this study due to discrepancies in previous CCT findings investigating soccer players during the pre-season [25, 26]. Thereafter, 18 male participants were recruited for this study, with a slightly higher number of participants than recommended in case any participants dropped out (e.g., logistical problems, injury, not related to the intervention). Eligibility criteria for this study required participants to be university soccer players who were in the pre-season training camp for inter-university competitions and were actively practicing the sports for a minimum duration of five hours per week, had a minimum of one year of resistance training experience, and were free from lower limb injuries six months before the study. Participants were randomly assigned (using randomization tool; www.randomizer.org) to either CCT (n = 9) or an active control group (CG; n = 9). Two participants in the CCT dropped out for logistical reasons before the start of the intervention. Participants within each group possessed similar demographics (Table 1). The potential risks and benefits of this study were explained to the participants before the study. Thereafter, informed consent forms were signed by participants. The local ethical committee of Lakshmibai National Institute of Physical Education, India approved this study.

Table 1. Participant demographics of complex contrast training (CCT) and active (soccer) control group (CG)

	CCT (n = 7)	CG (n = 9)	p-value*
Age (yrs)	21.6 ± 2.23	21.1 ± 2.03	0.672
Height (cm)	172.6 ± 8.7	175.2 ± 4.9	0.457
Body mass (kg)	63.7 ± 6.5	62.4 ± 5.9	0.152

Note: * – independent t-test.

Procedure

Before the start of the intervention, three familiarization sessions for the CCT exercises and two familiarization sessions for the testing procedures were conducted before the baseline assessments to reduce any learning effects. Demographic data were collected and 1RM tests were performed during these familiarization sessions. The 1RM assessments were conducted according to methods outlined in a previous study [24] to define the load prescription for each participant during the high-load activities (i.e., squat, lunges, Romanian deadlift, bench press). The 1RM obtained for squat, lunges, Romanian deadlift, and bench press were 107 ± 10 kg, 64 ± 8 kg, 91 ± 11 kg, and 69 ± 10 kg, respectively. No 1RM data was collected for the CG.

Furtheremore, participants were asked to refrain from any strenuous activity for 24 hours and were asked to eat a habitual meal and refrain from consuming caffeine for three hours before testing. A two (within-subject; pre-post) by two (between-subject; CCT, CG) randomized design was used to compare the effects of the training intervention on 30 m linear sprint, SLJ, CMJA, and peak torque of both legs during unilateral isokinetic tests (i.e., knee extension and flexion). Pre-post measurements were performed at similar times during the day for all participants to minimize circadian effects, with linear sprint, SLJ, and CMJA conducted on day one, and isokinetic testing conducted on a separate day (24-72 h after day one). The sequence of testing order was the same for all the participants. Upon arrival on each testing day, participants underwent a 10-minute general warm-up procedure.

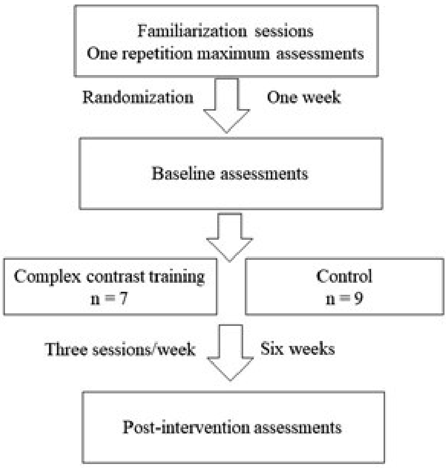


Figure 1. Schematic of the study design.

Training intervention

The training intervention was conducted for a duration of six weeks, with three sessions per week. The exercises used in the contrast pairs for CCT were based on previous studies [24, 31]. The details of the exercise prescription are provided in Table 2. The participants were asked to perform both the high-load as well as low-load activities with an intention (i.e., effort) to attain maximal velocity during the concentric phase of the movement. Furthermore, the low-load activity was performed immediately after (≤30 s) the high-load activity, with one minute of rest between consecutive sets, two minutes between the contrast pairs (i.e., between squat with CMJA and Romanian deadlift with kettlebell swings), and ≥48 hours between sessions. Both CCT and CG were involved in standard soccer training with morning sessions focused on strength and conditioning, and evening sessions focused on sport-specific technical-tactical aspects. The experimental group replaced three standard morning training sessions per week at the gym with CCT (details of the training programme in Table 2), while the CG underwent regular conditioning sessions focused on the improvement in physical fitness (e.g., repeated sprint ability, aerobic endurance), and did not get involved in any resistance or plyometric training sessions.

Physical fitness assessments

A 30 m linear sprint assessment was conducted based on protocol outlined in a previous study [33] on a synthetic outdoor track. Two timekeepers were recruited and assigned to record the timing of each trial using hand stop watches. An excellent between-timekeepers interclass correlation coefficient (ICC) was obtained (ICC= 0.99). An average of the times recorded by timekeepers was used for analysis. Standing long jump was conducted based on the methods outlined in a previous study [34] on a synthetic outdoor track. Three jumps were performed with one-minute rest between jumps, and the longest jump was selected for analysis. The CMJA was conducted using a reliable [35] inertial measurement unit (BTS G-walk, Italy) to measure the vertical jump height during CMJA. The protocol for the placement of the inertial measurement unit and jump was based on a previous study [35]. Three maximal effort trials were conducted with a recovery period of one minute between trials, with the best trial being selected for analysis. Furthermore, isokinetic tests to measure peak torque were conducted using a HUMAC NORM isokinetic dynamometer (Computer Sports Medicine Inc., Stoughton, USA). The protocol used was based on a previous study [24]. Two sets of test were conducted for each leg with the highest peak torque value being selected for analysis. The test-retest reliability of each assessment is presented in Table 3.

Table 2. Complex contrast training programme

	High-load (% 1RM) resistance exercise		**Low-load* plyometric/power exercise**	
	Exercise	Sets × repetitions	Exercise	Sets × repetitions
Weeks 1-2 65% 1RM	Squat	3 × 15	Squat jump	3 × 6
	Romanian deadlift	3 × 15	Kettlebell swing	3 × 10
	Barbell lunge	3 × 15	Barbell high knees	3 × 15 sec
	Bench press	3 × 15	Plyo-push up	3 × 6
Weeks 3-4 75% 1RM	Squat	3 × 10	Squat jump	3 × 8
	Romanian deadlift	3 × 10	Kettlebell swing	3 × 10
	Barbell lunge	3 × 10	Barbell high knees	3 × 20 sec
	Bench press	3 × 10	Plyo-push up	3 × 8
Weeks 5-6 85% 1RM	Squat	3 × 6	Squat jump	3 × 10
	Romanian deadlift	3 × 6	Kettlebell swing	3 × 10
	Barbell lunge	3 × 6	Barbell high knees	3 × 25 sec
	Bench press	3 × 6	Plyo-push up	3 × 10

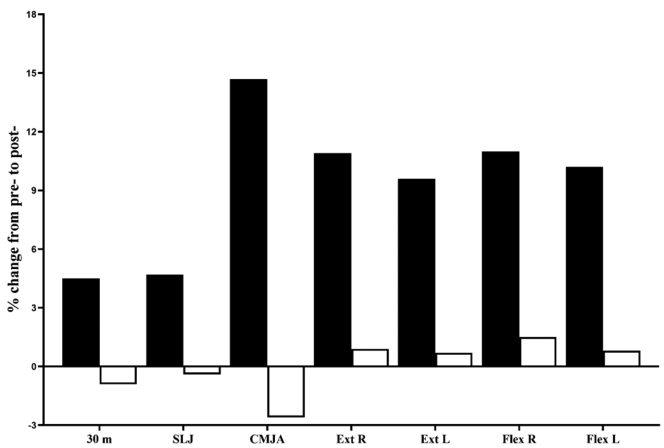
Note: 1RM – one repetition maximum; * – plyometric/power exercises usually involved body-mass load (i.e., CMJA and plyometric push-ups), with kettlebell swings involving 10-20 kg, and barbell high knees a 20 kg Olympic barbell.

Table 3. Test-retest reliability of assessments using interclass correlation coefficient (ICC)

Variable	**ICC (95% confidence interval)**
30 m linear sprint	0.99 (0.97-0.99)
Standing long jump	0.91 (0.76-0.97)
Countermovement jump	0.96 (0.87-0.98)
Peak torque leg extension (right)	0.99 (0.96-0.99)
Peak torque leg extension (left)	0.99 (0.96-0.99)
Peak torque leg flexion (right)	0.95 (0.87-0.98)
Peak torque leg flexion (left)	0.96 (0.88-0.98)

Statistical analysis

The analyses were conducted using IBM SPSS version 20.0.0 (IBM, New York, USA). The normality of data was verified using the Shapiro-Wilk test. Data are presented as means and standard deviations. A two (pre-post intervention) by two (CCT, CG) mixed ANOVA was used to analyze the exercise-specific effects. In addition, in case of significant group-by-time interactions, between-group comparisons at post with baseline scores as covariate were used for post-hoc analyses. Within group changes were analyzed using paired t-test. Percentage change scores were also calculated for each variable in each group using the equation in Microsoft Excel: [(meanpost – meanpre) / meanpre] × 100. Effects sizes (ES) in the form of partial eta squared ($\eta p2$) were used from ANOVA output. Hedge's g was calculated to assess changes between pre-post measurements testing for each group. The magnitude of effects for $\eta p2$ was interpreted as small (<0.06), moderate (≥0.06-0.13), and large (≥0.14) [36], while Hedge's g was interpreted as trivial (<0.2), small (0.2-0.6), moderate (>0.6-1.2), large (>1.2-2.0), very large (>2.0-4.0) and extremely large (>4.0) [37]. The ICC between trials and assessors was interpreted as poor (<0.5), moderate (0.5-0.75), good (0.75-0.9), and excellent (>0.9) reliability based on the lower bound of the 95% confidence interval (CI; ICC95%CI lower bound) [38]. Statistical significance was set at p ≤ 0.05.



Note: negative bars denote detrimental changes, CMJA – countermovement jump with arm swing height, Ext – knee extension for maximal torque, Flex – knee flexion for maximal torque, L – left, R – right, SLJ – standing long jump distance.

Figure 1. Relative (%) change in dependent variables between pre- and post-training intervention for the complex contrast training (black bars) and control group (white bars).

Results

Adverse effects

No participants dropped out of the study, sustained any injuries, or missed any training sessions.

Main outcomes

The results for all dependent variables of the main analysis are presented in Table 4, with a graphical representation of pre-post percentage change in Figure 2. No baseline differences (independent t-test p = 0.270 – 0.989) were observed between CCT and CG in any dependent variable.

There were significant time × group interaction effects for all the dependent variables (p < 0.001 to 0.004). Post-hoc using paired t-test revealed significant improvement in all dependent variables in CCT (p < 0.001 to 0.001; g = 0.29 – 0.96; %Δ = 4.5 – 14.7), but not in CG (p = 0.174 – 0.633; g = 0.03 – 0.20; %Δ = 0.4 – 2.6). Further, after the intervention, post-hoc tests with baseline scores as a covariate showed significant improvement in all dependent variables in CCT compared to CG.

Discussion

Compared to standard soccer training, six weeks of CCT with three weekly sessions improves athletic performance in highly-trained amateur male soccer players during the pre-season. The enhanced performance included a *small* magnitude improvement in SLJ distance (%Δ = 4.7) and peak isokinetic torque of both legs during extension/flexion (%Δ = 8.0 – 11.8), *moderate* improvement in 30 m linear sprint time (%Δ = 3.1) and CMJA height (%Δ = 13.3). Further, the CG showed a detrimental change in 30 m linear sprint, SLJ, and CMJA.

The findings of this study are in line with available CCT literature for soccer players [17, 18]. A recent meta-analysis [17] reported a *large* improvement in 30 m linear sprint performance and *moderate* improvement in CMJ performance after CCT among soccer players. In addition, another study [18] reported a *large* improvement in lower limb maximal strength after CCT.

Table 4. Statistical comparisons between experimental group and active control group

Variables	Complex contrast training group (n = 7)			Active control group (n = 9)			Time × group
	Pre-test	Post-test	p-value [g] Magnitude	Pre-test	Post-test	p-value [g] Magnitude	p-value [η_p^2] Magnitude
	Mean ± standard deviation			Mean ± standard deviation			
30 m sprint (s)	4.71 ± 0.2	4.50 ± 0.21	<0.001 [0.96] *Moderate*	4.48 ± 0.22	4.52 ± 0.19	0.174 [0.19] *Trivial*	<0.001 [0.70] [a] *Large*
Standing long jump (m)	2.34 ± 0.18	2.45 ± 0.18	0.001 [0.57] *Small*	2.41 ± 0.15	2.40 ± 0.17	0.633 [0.06] *Trivial*	0.004 [0.46] [a] *Large*
Countermovement jump with arm swing (cm)	39.94 ± 4.82	45.81 ± 6.7	<0.001 [0.94] *Moderate*	37.08 ± 5.04	36.11 ± 4.04	0.313 [0.20] *Small*	<0.001 [0.63] [a] *Large*
PT leg extension (right) (Nm)	180.9 ± 56.0	200.7 ± 54.4	<0.001 [0.34] *Small*	182.8 ± 53.3	184.4 ± 52.3	0.278 [0.03] *Trivial*	<0.001 [0.83] [a] *Large*
PT leg extension (left) (Nm)	194.3 ± 60.5	212.9 ± 60.5	<0.001 [0.29] *Small*	198.1 ± 33.9	199.4 ± 33.6	0.338 [0.04] *Trivial*	<0.001 [0.84] [a] *Large*
PT leg flexion (right) (Nm)	115.6 ± 22.3	128.3 ± 24.2	<0.001 [0.51] *Small*	110.1 ± 28.1	111.8 ± 25.7	0.211 [0.06] *Trivial*	<0.001 [0.70] [a] *Large*
PT leg flexion (left) (Nm)	110.3 ± 25.9	121.6 ± 26.1	<0.001 [0.41] *Small*	110.1 ± 23.5	111 ± 21.5	0.573 [0.04] *Trivial*	<0.001 [0.59] [a] *Large*

Note: g – Hedges' g; Nm – Newton meters; PT – peak torque; a – significant difference at post-test using baseline as covariate.

The performance increment in the CCT group may be attributed to specific neuromuscular adaptations that may have improved the stretch-shortening cycle, increased motor unit recruitment, firing frequency, intra-and-inter-muscular coordination, and morphological changes that help with muscle's force-generating capacity [13, 17, 18, 39]. Moreover, jump based activities have also shown to increase the reactive strength of the lower limbs [40], which is also associated with increased rate of force development. In addition, specific adaptations that optimize the force-velocity relationship may have occurred due to the incorporation of both high-load low velocity and low-load high velocity exercises (e.g., heavy squat with CMJ) [12]. Indeed, with a single mode exercise, it is possible to target higher percentage of the force or velocity component of the force-velocity spectrum [12], allowing a significant deficit at the other end of the spectrum. For example, heavy resistance exercise may majorly target the force component, thus improving the force-generating capacity, while the plyometric exercise may majorly target the velocity component, thus improving the velocity-generating capacity [41]. However, the inclusion of both heavy resistance and plyometric exercise in a single session as in CCT may have allowed adaptations across a more comprehensive force-velocity spectrum [12]. Furthermore, optimization of the force-velocity spectrum supports recruitment of fast twitch muscle fibers that underpin athletic performance (e.g., linear sprints) [20, 42].

A significant improvement in maximal strength was observed after four weeks of CCT intervention among youth male soccer players during the pre-season [26]. In line with previous findings, our findings support the effectiveness of pre-season CCT to improve knee flexors and extensors peak torque also in adult male highly-trained soccer players. Hormonal and structural adaptations such as increased testosterone concentration [43] and leg volume [44] have been previously observed after six weeks of CCT intervention. In addition, CCT may favour post-activation potentiation of performance [12], increasing neural activation of the musculature [45]. Indeed, a recent meta-analysis confirmed that sequencing high-load resistance and low-load plyometric exercise – as in CCT – is superior to other sequencing formats (e.g., descending sequencing) in improving athletic abilities such as sprints, jumps, and maximal strength [46]. Whether the the aforementioned physiological mechanisms may explain the increased peak torque in male soccer players after CCT remains speculative. Future studies may explore this relevant hypothesis.

There are limitations of this study that should be acknowledged. Firstly, the participants included in the study were amateur male soccer players. Therefore, the study findings should not be extrapolated to other groups (e.g., female soccer players). Secondly, the training intervention was limited to a six-week duration during the pre-season. Although a six-week period may replicate a typical soccer pre-season, a longer duration study including the in-season period may be needed to confirm the long-term adaptations. Thirdly, this study included a small sample size. Although we conducted a sample size estimation before conducting the study, larger sample size may be required to support current findings. Fourthly, the absence of biochemical or physiological data collection. Such data would provide a better interpretation of the results.

Conclusions

Compared to an active control group (i.e., standard soccer training), a six-week CCT intervention during the pre-season is effective in improving athletic performance (i.e., 30 m linear sprint, SLJ, CMJA height, and unilateral knee extension and flexion isokinetic peak torque) in highly-trained amateur male soccer players. The magnitude of improvements was *small* for SLJ and unilateral isokinetic strength, and *moderate* for 30 m sprint and CMJA. Therefore, CCT may be suggested as a supplementary training intervention to induce adaptations that favor atheletic performance development during the pre-season among highly-trained amateur male soccer players.

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