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THE EFFECTS OF 12-WEEK ECCENTRIC AND CONCENTRIC STRENGTH TRAINING ON THE PHYSICAL FITNESS CHARACTERISTICS OF FOOTBALL PLAYERS

UČINKI 12-TEDENSKEGA EKSCENTRIČNEGA IN KONCENTRIČNEGA TRENINGA MOČI NA TELESNO PRIPRAVLJENOST NOGOMETAŠEV

ABSTRACT

The aim of present study was to examine the effects of eccentric and concentric training applied to football players on some motor characteristics. A total of 23 university students playing soccer participated in the study voluntarily. Subjects were randomly divided into two groups; complex (ECC_{st}) and contrast (CON_{st}) training protocols. During 12-weeks, ECC_{st} and CON_{st} training groups performed strength training in addition to soccer training 3 days a week, over 7 hours (4-5 units). On the first day, one repetition maximum (1RM) strength tests of all subjects were measured respectively. On the second day, all athletes' height, body weight, body fat ratio, vertical jump, and sprint (20 m) tests performance tests were measured at the beginning and end of the 12-weeks study. As a result, although there was a statistically significant difference between the pre and post (lying leg curl, machine abduction, machine adduction 1RM) and vertical jump test of the subjects in both ECC_{st} and CON_{st} training group in terms of time effect, a significant difference was found in favor of the ECC_{st} in the group x time interaction of ECC_{st} training compared to CON_{st} ($p<0.05$). There was no statistically significant difference between the groups in the (1RM leg extension) and 20 m sprint performance tests ($p>0.05$). As a result revealed that 12-weeks ECC_{st} more effective than CON_{st} in improving lower extremity strength and vertical jump of soccer players. There were similar increases in both ECC_{st} and CON_{st} in 1RM leg extension and 20m sprint.

Keywords: Strength, training, football, vertical jump, sprint

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IZVLEČEK

Namen pričujoče študije je bil preučiti učinke ekscentričnega in koncentričnega treninga na nekatere parametre telesne zmogljivosti nogometašev. V raziskavi je prostovoljno sodelovalo 23 študentov noogmetašev. Preiskovanci so bili naključno razdeljeni v dve skupini; skupino kompleksnih (ECCst) in skupino kontrastnih (CONst) vadbenih protokolov. V 12 tednih sta vadbeni skupini ECCst in CONst poleg nogometnega treninga izvajali trening moči 3 dni v tednu po 7 ur (4-5 enot). Prvi dan so bili izmerjeni testi moči z eno ponovitvijo (1RM) za vse preizkušance. Drugi dan so na začetku in koncu 12-tedenske študije izmerili teste učinkovitosti testov višine, telesne mase, telesne maščobe, navpičnega skoka in šprinta (20 m) vseh športnikov. Ugotovili smo statistično pomembno razliko med pred in post testu v sledečih gibalnih testih: ukrivljenost nog v ležečem položaju, strojna ugrabitev, strojna abdukcija 1RM in testu vertikalnega skoka. Ugotovili smo pomembno razliko med vadbenima skupinama ECCst in CONst glede na časovni učinek v korist ECCst ter značilno razliko v skupini x časovna interakcija ECCst treninga v primerjavi s CONst ($p<0,05$). Med skupinama ni bilo statistično značilne razlike v testu uspešnosti (1RM izteg noge) in 20 m sprint ($p>0,05$). Ugotovili smo, da je 12-tedenski ECCst učinkovitejši od CONst pri izboljšanju moči spodnjih okončin in navpičnega skoka nogometašev. Značilno se je povečal tako ECCst kot CONst v 1RM iztegovanju noge in šprintu na 20 m.

Ključne besede: moč, trening, nogomet, navpični skok, sprint

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INTRODUCTION

For elite athletes, a high level of physical fitness is one of the prerequisites for success. The main components of football-specific fitness include acceleration, anaerobic repetitive sprinting ability, and the explosive strength of the lower extremities. These components are associated with force generation, especially during running, turning, hitting the ball, jumping (Psotta et al., 2011; Stolen, Chamari, Castagna, & Wislof, 2005). Football is considered to be a branch of sports played by combining intermittent movements in motion analysis (Di Salvo et al., 2005; Erol, & Arabaci, 2021). In a typical football game, players perform short actions every 3–5 seconds, with 30-40 sprints, 30-40 jumps. These are actions such as slowing down from the original direction as quickly as possible and accelerating in a new direction, jumping, hitting the ball, and dribbling, (Bangsbo, 1994; Morh et al., 2005). The optimization of actions and related factors becomes essential as the high levels of these high-intensity football actions and activities increase in today's competitive football matches (Bush, Barnes, Archer, Hogg, & B, Bradley, 2015). In this line, the main aim of strength training was to improve the technical and tactical capacity of the players and the game (Brito, Vasconcellos, Oliveira, Krustrup, & Rebelo, 2014). Different resistance training models have been used to improve physical performance in soccer, such as programs based on traditional sports (Kotzamanidis, Chatzopoulos, Michailidis, Papaiakovou, & Patikas, D.2005). Resistance training models included eccentric strength training (ECC_{st}) and concentric strength training (CON_{st}) (Kraemer, W. J., & Ratamess, N. A. 2004).

Muscle contractions show differences in mechanical, metabolic, and neural control during ECC_{st} and CON_{st} (Franchi, Reeves, & Novici, 2017). These two different contractions are known to stimulate neuromuscular activity differently and cause different compliance after exercise. CON_{st} is a powerful training method supported by the assumption of the neuromuscular system (Argus, Gill, Keogh, McGuigan, & Hopkins, 2012) while ECC_{st} includes more specific neuromuscular features than CON_{st} (Enoka, 1996; Carrasco, Delp, & Guilhem, Cornu, Maffiuletti, & Guével, 2013; González et al. 2013). At the same strength level, ECC_{st} exercises are characterized by lower metabolic needs and also require less muscle activity compared to CON_{st} exercises (Julian et al., 2018). Since a certain angular velocity is formed during an eccentric contraction, greater power is produced compared to other contraction types (Hortobagyi & Katch, 1990). ECC_{st} exercise can improve skeletal muscle performance with lower oxygen requirement compared to CON_{st} exercise (Perry, Betik, Candau, Rouillon, & Hughson, 2001). ECC_{st} exercises include isoinertial or isokinetic segmental contractions

(Coratella, & Schena, 2016). Skeletal muscle generates force either by shortening (concentrically) or lengthening (eccentrically). Eccentric training has been shown to produce more muscle hypertrophy than concentric training (Seger et al., 1998). Due to its specific physiological and mechanical features, the eccentric contraction has gained increasing attention in several areas (Roig et al., 2008).

When reviewed the studies conducted on the development of explosive power outputs in the literature, generally the concept of "optimal loading" has been used (Cronin, 2005). Gravitational exercises that have been used to improve physical performance in football, which are similar to traditional sports-based programs, include plyometric exercises, ballistic exercises, weight training with submaximal and maximal loads, or a combination of these methods (Faude, Di Giovine, & Zahner, 2013). However, similar studies carried out to date have been carried out with short-term training plans covering 6-11 weeks.

Strength training in football has been observed to improve physical abilities increasing the sports efficiency during the matches (Alves, Rebelo, Abrantes, & Sampaio, 2010). Sports activities (e.g. football) where the lower extremities are more exposed to explosive force are performed with a combination of CON_{st} and ECC_{st} muscle contractions (Faude, DiGiovine, & Zahner, 2013). For many years, eccentric exercise regimes have been used extensively in sports training to develop maximum muscle strength, power, and coordination during eccentric tasks. While studies have focused mainly on functional outcomes following eccentric resistance training using high loads, the potential of low/medium load regimes has attracted much attention in the last decade (Hoppeler, 2016). Football is a team sports, therefore, most of the training programs implemented included activities aimed at improving the physical fitness of athletes needed during the matches (Arabaci, Pehlivan, & Gorgulu, 2020). Coaches may feel the need to rationalize the time and volume allocated to strength training programs as a strategy to ensure that players are successful in their projected training program. As the hypothesis of this study, we can demonstrate that ECCst can be more effective than CON_{st} due to the forced elongation of the muscle-tendon system during the contraction of skeletal muscles. The aim of present study was to investigate the effects of 12-week ECC_{st} and CON_{st} on football players' strength, 20 m sprint and vertical jump.

METHODS

Participants

A total of 23 university male students with at least 5 years of football training experience, playing in the university team participated voluntarily. Three subjects were excluded from the study due to unwillingness to participate in the study since the first measurement, transfer to another team, illness, and not being able to follow the regular schedule. The study was completed with 20 subjects (Mean age 21.80 ± 1.71 years, height 177.4 ± 6.47 cm and weight 77.21 ± 10.19 kg). All subjects reported being free from illness and injury at the time of the experiment. After the advantages and disadvantages, they may encounter during the applications were explained in detail, the subjects read and signed the consent form before the study. Subjects whose wanted to quit the study of their own free will and those who experienced psychological or physical trauma during the study were excluded from the study. Also, those whose blood pressure and heart rate values before and after the exercise test were out of physiological levels were excluded from the study. The ethical permission was obtained from Bursa Uludag University Health Sciences Research and Publication Ethics Committee (date 14.09.2018, No: 2018-05).

Training design

Subjects were randomly divided into 2 groups according to the experimental protocols to be applied. During 12 weeks, in addition to a total of 7 hours (4-5 session) of soccer training per week, while one of the groups (n = 10) performed ECC_{st}, the other group (n =13) performed CON_{st} for 3 days/wk. ECC_{st} and CON_{st} training programs are shown in Table 1. Strength training of the ECC_{st} group included high step, eccentric back squat, eccentric, barbell drop lunge, leg press, eccentric Romanian deadlift (RDL) and strength training of the CON_{st} group included leg extension, lying leg curl, deadlift, concentric back squat, seated leg curl. Loading method in ECC_{st} and CON_{st} program presented in Table 1 (70% x 10, 80% x 7, 85% x 5, 85 % x 5 80% x 7, 70% x 10) sets, 2-4 min rest between sets and 1 min of rest between repetitions (Bompa, 1989; Kolukısa, 2015). The following tests were carried out by subjects as pre-test at the beginning and post-test at the end of the 12 week experimental program.

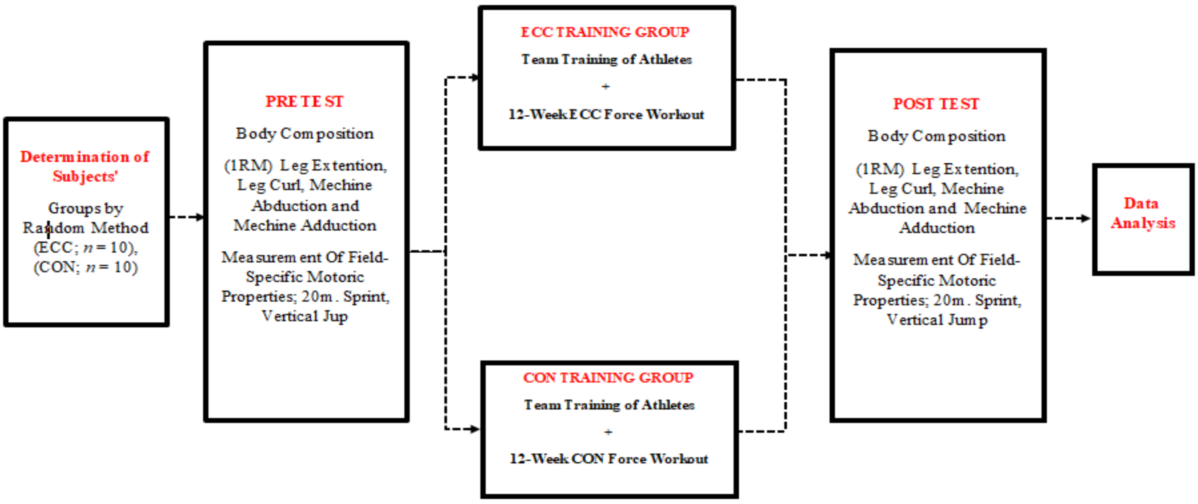
Table 1. Eccentric and Concentric Training Program.

Variables	ECC	CON
Duration (week)	12	12
Frequency (day/week)	3	3
Sets (number)	5	5
Recovery/sets (min)	2-4	2-4
Recovery / exercise (min)	1	1
Ecc and con runtime (sec)	1sec CON - 3sec ECC	3 sec CON-1 sec ECC
Intensity (%) and repetition.	70% x 10 rep,	70% x 10 rep,
	80% x 7 rep,	80% x 7 rep,
	85% x 5 rep,	85% x 5 rep,
	85% x 5 rep,	85% x 5 rep,
	80% x 7 rep,	80% x 7 rep,
	70% x 10 rep	70% x 10 rep

Experimental design

Before and after the 12-weeks ECC_{st} and CON_{st} training program, a 2-day test set, carried out on non-consecutive days. On the first day height, weight and body fat% were measured then 1RM leg extension, lying leg curl, machine abduction, and adduction were determined respectively, second day vertical jump and 20 m sprint drill tests were carried out. All tests were carried out in the fitness center where the training program was performed, and two assistants necessarily helped the subjects during tests. Second day tests were performed twice for each participant and best performances were recorded. Before the tests, a general and specific warm-up was performed for 20 min. The subjects had not performed any intense training (loading) within 24 hours before the test (Figure 1).

Figure1. Flow chart of intervention.



Measurements

Body Composition: Subjects' heights were measured barefoot using a precise height scale (Soehnle-Waagen GmbH & Co. KG). Bodyweight was measured using a bioelectrical impedance device (TANITA, TBF-300, Tokyo, Japan) barefoot while the subjects had light clothing on.

1 Repetition Maximum Tests (1RM): 1 RM of the study was determined according to the Brzycki equation. According to this formula, 1RM is estimated as follows: 1RM= Weight ÷ (1.0278 - (0.0278 × Number of repetitions (Brzycki, 1993).

Sprint (20m) Test: After the 20 m distance was drawn as a track, a wireless 2-gate Sinar (Turkey) photocell device has been fitted. The photocell started the measurement the moment the players started the sprint right after the starting photocell, and when the gate located at 20 meters was passed, the values were transferred to the computer via the Sinar software. The test was performed twice with the athletes and the best value was taken into the study. During the measurements, the athletes were verbally motivated to give a maximal performance.

Vertical Jump Test: The vertical jump test is one of the most commonly used tests to measure strength and explosiveness (Miller, 2012). The highest point where the participants could reach with their feet on the ground and the body in an upright position was considered as the starting point, and they were asked to jump to the highest point without taking a step. The difference between the starting and the highest point reached has been considered as the vertical jump value (Nieman, 2011). The best of three attempts was taken and recorded.

Statistical Analysis: Within each study group 2 (training group: ECC_{st}, CON_{st}) × 2 (time: pre and post - test) fully repeated measures ANOVA were used to make comparisons over the 12 - weeks training sessions for the ECC_{st} and CON_{st} groups separately for pre and post measurements. When applicable, training induced changes within groups (work/set, ECC_{st} and CON_{st}) were performed using a paired samples *t* test. The Effect Size Cohen's d was calculated, which was considered small (0.20), medium (0.50), or large (0.80). Values reported are mean and standard deviation (SD). The significance level was set to $p < 0.05$.

RESULTS

In this study**,** the effects of 12-week ECC_{st} and CON_{st} on some physical fitness features of football players (lower extremities) were investigated. The results obtained as a result of the statistical analysis, which was explained in detail in the data analysis sub-section of the method section, descriptive statistics, and the differences between pre-test and post-test variables are presented in a table 2.

Table 2. Descriptive characteristics of ECC_{st} and CON_{st} groups.

Variables	**ECC_{st} (n=10)**			**CON_{st} (n=10)**		
	$\bar{x}$ (SD)	*Min*	*Max*	*$\bar{x}$ (SD)*	*Min*	*Max*
Age (years)	21.70 (1.70)	20	25	21.90 (1.72)	20	26
Height (cm)	178.90 (7.32)	165	190	175.90 (5.62)	167	185
Weight (kg)	81.20 (10.03)	61.30	94	73.23(10.35)	61	90.30
BMI (kg/m^2)	24.93 (2.37)	22.00	29.80	23.75 (2.83)	19.70	28.50

*ECC_{st}: eccantric strength training; CON_{st}: concantric strength training; BMI: Body mass index

As shown in Table 2 descriptive characteristics of ECC_{st} and CON_{st} (mean ± SD) age 21.7±1.7 years and 21.9±1.72 years, height 178.9±7.3 cm and 175.9±5.6 cm, weight 81.2±10.0 kg and 73.2±10.3 kg, BMI 24.9±2.3 kg /m^2, and 23.7±2.8 kg /m^2 respectively were determined.

Table 3. Comparison of the changes in 12-weeks training between ECC_{st} and CON_{st} groups.

Measures	ECC_{st} Pre	ECC_{st} Post	CON_{st} Pre	CON_{st} Post	*F*	*P*	η_p^2
Leg extension (kg)	103.60	108.40	101.00 (10.68)	104.70 (10.	.91	.36	.09
Lying leg curl (kg)	57.20 (5.18)	62.10 (5.68)	56.60 (5.89)	59.50 (6.53)	8.57	.02*	.48
Machine Abduction	95.50 (9.38)	101.00	88.10 (11.39)	91.10	5.83	.04*	.39
Machine Adduction	87.50	93.10	80.00 (10.50)	83.20	13.50	.01**	.60
Vertical jump(cm)	47.70 (4.37)	52.00 (4.29)	47.40 (5.92)	48.80 (5.76)	10.98	.01**	.55
Sprint(20m) (sn)	3.03 (0.18)	2.93 (0.51)	3.17 (0.24)	3.15 (0.25)	3.70	.08	.29

*: $p < .05$; **: $p < .01$; ***: $p < .001$; ECC_{st} : eccantric strength training; CON_{st}: concantric strength training

According to the analysis results in Table 3 a statistically significant difference was found between the groups in favor of the ECC_{st} in leg curl (pre 57.2±5.18 kg - post 62.10±5.68 kg vs. CON_{st} pre 56.60±5.89 kg - post 91.10±11.51) machine abduction (pre 95.50±9.38 - post 101.00±10.68 kg vs. CON_{st} pre 88.10±11.39 kg - post 91.10±11.51kg) machine adduction (pre 87.50±11.74 kg - post 93.10±12.33 kg vs. CON_{st} pre 80.00±10.50 kg - post 83.20±10.60 kg) and vertical jump (pre 47.70±4.37 cm - post 52.00±4.29 cm vs. CON_{st} pre 47.40±5.92 cm - post 48.80±5.76 cm). However, there was not a statistically significant difference between ECC_{st} and CONst in the leg extension (ECC_{st} pre 103.60±8.89 kg - post 108.40±8.08 kg vs. CON_{st} pre 101.00±10.68 kg - post 104.70±10.67 kg), 20 m sprint (ECC_{st} pre 3.03±0.18 sec - post 2.93±0.51sec vs. CON_{st} pre 3.17±0.24 sec - post 3.15±0.25 sec) values.

DISCUSSION

The present study was carried out particularly to evaluate the chronic effects of ECC_{st} and CON_{st} and to compare their effects on lower extremity muscles strength, vertical jump and sprint (20m). According to the main findings obtained from the 12-weeks study, although both ECC and CON training provided significant improvement in lower extremity muscles strength (1RM leg extension, lying leg curl, machine abduction, machine adduction). ECC_{st} training was found to be significantly superior to CON_{st} training in lower extremity muscle strength in comparison between groups. Also, both of ECC and CON trainings showed significant increases in vertical jump skills in terms of time effect, but there was no significant difference between groups. In (20m) sprint tests, there was no significant improvement in both ECC_{st} and CON_{st} training.

Strength training program with a load intensity (70% x 10, 80% x 7, 85% x 5, 85% x 5, 80% x 7, 70% x 10) was applied 3 days/week for 12 weeks in both groups as 3 sets with the recovery of 2-4 min. between sets and 1 minute between the reps. In this strength training program, ECC_{st} strength training was applied to the ECC_{st} group, and CON_{st} strength training was applied to the CON_{st} group. As far as we know, this training method was carried out for the first time. EEC_{st} and CON_{st} strength training, which has been used to improve physical performance in football players in previous studies, includes the combination of weight training and methods with high load intensity (submaximal - maximal) loads (Ishoi et al., 2018). In our study, load intensity (optimal) was performed in the range of 70% -85%. Similarly, the maximal force generated during eccentric muscle contractions has been shown to be significantly greater than that generated during concentric muscle contractions (Franchi et al., 2017). An important evidence group has demonstrated the better of eccentric resistance training over concentric or conventional strength training in terms of muscle hypertrophy and muscle strength (Julian et al., 2018) The maximum power in eccentric training has been determined to be approximately 20–50% greater than concentric training (Bamman et al., 2001). While there is evidence that eccentric training results in significantly greater increases in muscle strength, the differences in isometric and concentric measurements seem to be less significant (Roig et al., 2009) The results also showed that the increase in eccentric strength after eccentric training was greater than the gain in concentric strength after concentric training (Vikne et al., 2006). Performance in actions involving the muscle strength or stretch-shortening cycle (such as vertical jump) has shown greater improvements with eccentric training compared to concentric or traditional resistance training (Douglas et al., 2017). Eccentric training has been shown to positively affect vertical jumping performance in football players (Thomas et al. (2009). The better of eccentric training in terms of strength and dynamic balance has been demonstrated (Booysen, Gradidge, & Watson, 2015). It has been shown that bi-weekly eccentric training performed by young footballers improves important components of athletic performance over standard in-season training (Sedanove et al., 2011). Eccentric training has been recommended to be systematically incorporated into training programs of eccentric-based protocols for most competitive sports for performance enhancement (Isner et al., 2013).

When the literature was reviewed, there are a limited number of studies conducted on EEC and CON_{st} strength training programs in the optimal load intensity. Besides, while most of the recent studies conducted on football have investigated the effects of short-term training planning (6-11 weeks), in this study, the effects of a 12-week long training have been investigated. More effective results can be obtained clinically if EEC_{st} and CON_{st} strength training, performed in the optimal load intensity ranging between 70% -85% is applied in different age and performance groups. Therefore, this study can be useful for obtaining better statistical data and achieving predetermined goals with Analyses.

Although there are many unique aspects of the study, there have been some limitations to pay attention to. Lower extremity strength (1RM test) values can be compared by selecting full professional athletes instead of athletes from the university football team and creating groups with equivalent strength values. Moreover, the number of participants in this study was similar to other studies evaluating strengthening methods in team sports; our sample size was relatively small. Larger sample size may have given more precise results.

CONCLUSION

As a result, 12-weeks ECC_{st} training more effective in improving lower extremity strength (1RM lying leg curl, machine abduction, machine adduction) and vertical jump of soccer players than CON_{st} training programs. There were similar increases in both ECC_{st} and CON_{st} in (1RM leg extension) and 20 m sprint. According to the findings of present study, while ECC_{st} is recommended to coaches for strength development of soccer players, both training methods can be recommended to improve speed and anaerobic power performances.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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