2024, Retos, 58, 1079-1086

The effect of resistance training focused on eccentric phase and interval exercises in young football players
El efecto del entrenamiento de resistencia se centró en ejercicios de fase excéntrica y de intervalos en jugadores de fútbol jóvenes

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Abstract. The cardiovascular system, strength, speed, and agility are essential for a football player to perform better. For this purpose, finding the best and shortest way has always been a challenge. Therefore, this study aims to examine the effect of resistance training focused on eccentric phase and interval exercises on strength, agility, speed, and cardio strength in young football players.40 young football players are divided into two groups. The control group (CG) received only typical football exercises (by their coach), and the experimental group (EG) experienced eccentric exercises combined with interval aerobic training. To measure strength, agility, speed, and cardio strength, the Squat test, T-test, 60-meter sprint, and Cooper test were performed, respectively. To compare pre and post-test, paired sample t-test was utilized, and compare the two groups ANCOVA and Quade Nonparametric Analysis of Covariance test were used. The paired sample t-test showed a significant difference between pre and post-test in strength and cardiac strength in both groups. However, no significant difference was observed in speed and agility in CG. However, in EG, there was a significant difference between the pre and post-test in speed and agility variables. Also, according to the ANCOVA and Quade Nonparametric ANCOVA results, there was a significant difference between CG and EG in all variables. Eccentric and interval aerobic training could be more effective than typical football exercises on strength, cardio, speed, and agility. Football players can use the present program training to improve the essential physical factors.
Keywords: Strength, Agility, Sprint, Male.

Resumen. El sistema cardiovascular, la fuerza, la velocidad y la agilidad son fundamentales para que un futbolista tenga un mejor rendimiento. Para ello, encontrar el mejor y más corto camino siempre ha sido un desafío. Por lo tanto, este estudio tiene como objetivo examinar el efecto del entrenamiento de resistencia centrado en ejercicios de fase excéntrica y de intervalos sobre la fuerza, agilidad, velocidad y fuerza cardiovascular en jugadores de fútbol jóvenes. Se divide a 40 jugadores de fútbol jóvenes en dos grupos. El grupo de control (CG) recibió sólo ejercicios típicos de fútbol (por parte de su entrenador), y el grupo experimental (EG) experimentó ejercicios excéntricos combinados con entrenamiento aeróbico a intervalos. Para medir la fuerza, agilidad, velocidad y fuerza cardiovascular, se realizaron el test de sentadilla, el test T, el sprint de 60 metros y el test de Cooper, respectivamente. Para comparar la prueba previa y posterior, se utilizó la prueba t de muestras pareadas y para comparar los dos grupos, se utilizó la prueba ANCOVA y el análisis no paramétrico de covarianza de Quade. La prueba t para muestras pareadas mostró una diferencia significativa entre la prueba previa y posterior en la fuerza y la fuerza cardíaca en ambos grupos. Sin embargo, no se observaron diferencias significativas en velocidad y agilidad en CG. Sin embargo, en GE hubo una diferencia significativa entre el pre y el post-test en las variables de velocidad y agilidad. Además, según los resultados de ANCOVA y ANCOVA no paramétrico Quade, hubo una diferencia significativa entre GC y EG en todas las variables. El entrenamiento aeróbico excéntrico y por intervalos podría ser más efectivo que los ejercicios típicos del fútbol en cuanto a fuerza, cardio, velocidad y agilidad. Los futbolistas pueden utilizar el presente programa de entrenamiento para mejorar los factores físicos esenciales.
Palabras claves: Fuerza, Agilidad, Sprint, Masculino.

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Introduction

Agility is defined as the body's ability to respond to a stimulus with a rapid whole-body movement with a change of direction and velocity (Sheppard & Young, 2006). Speed is the total distance traveled, in the unity of time, by the body (Stöggl, Enqvist, Müller, & Holmberg, 2010). Function, agility, and speed are essential performance determinants in football and many sports. Many training methods have been introduced to improve these factors, and to find a more efficient method is now top of the table. Some studies demonstrated that agility performance improvement was associated with eccentric strength of the knee flexor (Chaabene, Helmi, Prieske, Negra, & Granacher, 2018; Keiner et al., 2013).

Functional and neuromuscular changes induced by training based on the mode of exercise performed are specific. The factors that can play a role in exercise-induced muscle adaptations are subcellular damage, degree of mechanical tension, and metabolic stress (Duclay, Martin, Robbe, & Pousson, 2008; Hedayatpour, Falla, Arendt-Nielsen, & Farina, 2008; Hedayatpour, Falla, Arendt-Nielsen, & Farina, 2010). Concentric, eccentric, and isotonic are the types of muscle contraction utilized during exercise. However, the distinction between eccentric and the other types is that the muscle lengthens under tension. During this type of contraction, the force developed by the muscle is less than the load on the muscle, and therefore the muscle is stretched, and a lengthening contraction is produced. Muscle microlesions and greater mechanical tension are the characteristics of eccentric training compared to other contractions. Therefore, it can lead to more excellent muscle adaptation (Hedayatpour & Falla, 2015). Most of the introduced training methods can cause

2024, Retos, 58, 1079-1086

muscle adaptation, but which method can maximize adaptation.

Most of the time, an eccentrically little exercise can cause ultra-structural damage to skeletal muscle. The symptoms of this damage (like disrupted sarcomeres in myofibrils) are the elevation of muscle proteins in the blood, swelling, reduction of range of motion, delayed-onset muscle soreness, and impairment of proprioceptive function and neuromuscular control. In addition, eccentric exercise can lead to pain (Mohammadi & Williams,). Based on studies, overstretching of sarcomeres is the beginning of the damage process (Mirzayev, 2017). But there is an alternative view that states the beginning point is damage to components of the excitation-contraction coupling process (Hinks et al., 2021). Although all mentioned symptoms seem negative, there are possible positive later changes. Across different regions of the same muscle, muscle strain may be heterogeneous, which implies molecular, structural, and morphological adaptation (Kellis, 2018). These adaptations are not uniform within the muscle (Franchi et al., 2018). For instance, the length of sarcomeres in the distal region of the anterior tibialis muscle is longer than the proximal region (Pincheira, Boswell, Franchi, Delp, & Lichtwark, 2022). After the first week of eccentric exercises, there is much less stiff and sore. According to the literature, the weakest sarcomeres in myofibrils experience the most length changes (Proske & Morgan, 2001). Therefore, a long-term adaptation of eccentric exercises is that fewer myofibrils can reach to yield point. Moreover, caffeine can be used to recover the post-exercise deficit in tension (Proske & Morgan, 2001).

Compared to equivalent moderate continuous exercise, the interval of high-intensity exercise affects the capacity to perform external work (Keating, Johnson, Mielke, & Coombes, 2017). Although there are lowered training volumes and time spent exercising in intervals of high-intensity exercise, it affects musculoskeletal remodeling, metabolic, and cardiopulmonary as much as continuous endurance training (Burgomaster et al., 2008; Hafstad et al., 2011; MacInnis & Gibala, 2017). There is a heterogeneity in findings apropos of the necessity of strength and power for speed and agility (Ahmad & Diekin, 2020; Brown & Ferrigno, 2014; Herridge, Turner, & Bishop, 2020). In agility, both two types of muscle action are required for quick deceleration (eccentric action) and acceleration (concentric action). For the control of movement to change the body direction (agility), the eccentric action of muscle plays an essential role. Based on previous findings, eccentric training regimes can be a promising approach to enhancing speed and agility (Chaabene, Helmi, Prieske, Negra, & Granacher, 2018). Liu et al. found out that eccentric overload training is effective in enhancing eccentric overload training performance compared to the control group (Liu, Liu, Clarke, & An, 2020). A review by Chaabene et al. showed that the effect of eccentric exercises on change of direction speed performance in an athlete is small to significant (Chaabene, Helmi, Prieske, Negra, & Granacher, 2018). Moreover, some cross-sectional studies demonstrated a statistically significant correlation (moderate to large) between the change of direction speed performance and eccentric muscle strength in adult male and female athletic population (Chaabene, H., 2017; de Hoyo et al., 2016; Jones, Thomas, Dos' Santos, McMahon, & Graham-Smith, 2017; Spiteri, Cochrane, Hart, Haff, & Nimphius, 2013).

Considering the effect of eccentric exercises on muscles and providing and rendering a procedure and method of exercise with high efficiency is crucial for a high competition level. Therefore, this study aims to examine the effect of eccentric exercises on function, agility, speed, and cardio strength in young football players.

Materials and Methods

Participants

Forty football players were recruited for this research. They were randomly divided into the experimental group (n=20) and the control group (n=20). Inclusion criteria are: (1) not having surgery in the last six months, (2) not having any clinical problems, (3) between 18-30 years old, (4) being a football player (for at least ten years) and being in the First Division League. Variables of this study were strength, agility, speed, and cardio strength which were assessed with squat, T-test for agility, 60-meter, and Cooper test, respectively.

Training program

In this study, 12-week resistance training focused on the eccentric phase, and the interval was given to the experimental group. This program was performed in addition to regular football training. At the same time, the control participants experienced only regular football training.

The program training divided to three parts. (1) Week 1-4, (2) week 5-8 and (3) week 9-12. The first four weeks were general exercise (3 sessions per week). Also, the subjects were given aerobic exercises 2 sessions per week, 60 min with 65% MHR (Maximum Heart Rate) each session. The second four weeks (weeks 5-8) focused on the lower and upper extremities and core, two sessions per week. The tables below illustrate the exercises for the second four weeks. Aerobic training for the second 4 weeks: it was interval aerobic exercises and contained two pieces of training; first, three sets of 20-minute running with 6 min rest in between, and second, four sets of 15-minute running with 4 min rest in between. And one session per week, subjects played in the smaller field with a lower number.

In the last four weeks (weeks 9-12), football players experienced a training program with agility and plyometric ex-

2024, Retos, 58, 1079-1086

ercises; in addition, two sessions per week of general exercises (3 sets, 15-30 reps with 60-70% maximum exercises) and one session per week 60 min running (at least 12 km) with 65% MHR (Maximum Heart Rate). Furthermore, in this period, subjects had an exhibition game per week.

Table 1.
Training program.

No	Exercise	ST	Reps	RST	Exercise	ST	Reps	RST
1	Back squat	3	12	90	Squat	5	75-90% 1RM; 2-4-6-8, and the final or fifth set 70%1Rm until the athlete can not repeat	3-5
2	Lying leg curls	3	12	90	Lying leg curls	8	75-90% 1RM; 2-4-6-8, and the final or fifth set 70%1Rm until the athlete can not repeat	3-5
3	Leg Extensions	3	12	90	Leg Extensions	8	75-90% 1RM 2-4-6-8, and the final or fifth set 70%1Rm until the athlete can not repeat	3-5
4	Dead lift	3	12	90	Dead lift	5	75-90% 1RM 2-4-6-8, and the final or fifth set 70%1Rm until the athlete can not repeat	3-5
5	Barbell Bench Press	3	10	90	Barbell Bench Press	4	75-85% 1RM 15-8-10-15	1-2
6	Leverage incline chest press	3	10	90	Leverage incline chest press	4	75-85% 1RM 15-8-10-15	1-2
7	Barbell shoulder press	3	10	90	Barbell shoulder press	4	75-85% 1RM 15-8-10-15	1-2
8	Behind the neck press	3	10	90	Behind the neck press	4	75-85% 1RM 15-8-10-15	1-2
9	Side lateral raise	3	10	90	Side lateral raise	4	75-85% 1RM 15-8-10-15	1-2
10	Front dumbbells raise	3	10	90	Front dumbbells raise	4	75-85% 1RM 15-8-10-15	1-2
11	Seated cable row	3	10	90	Seated cable row	4	75-85% 1RM 15-8-10-15	1-2
12	H machine row	3	10	90	H machine row	4	75-85% 1RM 15-8-10-15	1-2
13	Crunches	3	10	90	Crunches	4	20 with weight	1
14	plank	3	1 min	90	Plank	4	2 min	1
15	Reverse Crunch	3	20	90	Reverse Crunch	4	20	1

Note 1: ST: Sets; RST: Rest in minutes. Note 2: During this 12-week, football players were given technique and tactics training by their coach (2 sessions per week) Note 3: During this 12-week, all the resistance training, the eccentric phase, took 2-4 seconds. Note 4: To assess 1RM, the below formula was applied (Özhan, 2012). 1 RM = weight/ (1,0278-(0,0278 x repetition).

Variables

Independent variable: 12-week resistance training focused on eccentric phase and interval. Dependent variables: strength, agility, speed, cardio strength.

Instruments

The instruments are: (1) T test, In this test, there are 4 points (start, point 1, 2, and 3). subject starts this test from the start point running forward to point 1 (10 meters), then sidestepping to point 2 (5 meters to the right), after that sidestep to point 3 (5 meters to left from point 2), then back to point 1 and to step back to start point (Figure 1). (2) 60-meter test, the 60-meter test or 60 meters sprinting speed test is a test that involves running a single maximum sprint for 60 meters, and the time of finishing this distance is recorded. (3) Cooper test, this test is utilized to monitor aerobic endurance of athletes and to have estimation of VO2max. For this test subjects had to run on the running track for 12 min, as much distance as they could. The distance was taken as their record. (4) Squat test, this test was performed to measure the strength of the subjects. 1RM of the squat test was recorded as the maximum weight the subjects could lift using good form and the full range of motion. If the repetition was correct in shape and range of motion, the weight was increased by 1-10 KG. This increment was based on the required effort to lift the weight, which progressively decreased as it reached 1RM. 1RM was determined on average within six trials. Failure in repetition is, as defined, any losing correct shape and lift falling short of the full range of motion for at least two attempts with 4 min rest between them (Masamoto, Larson, Gates, & Faigenbaum, 2003).

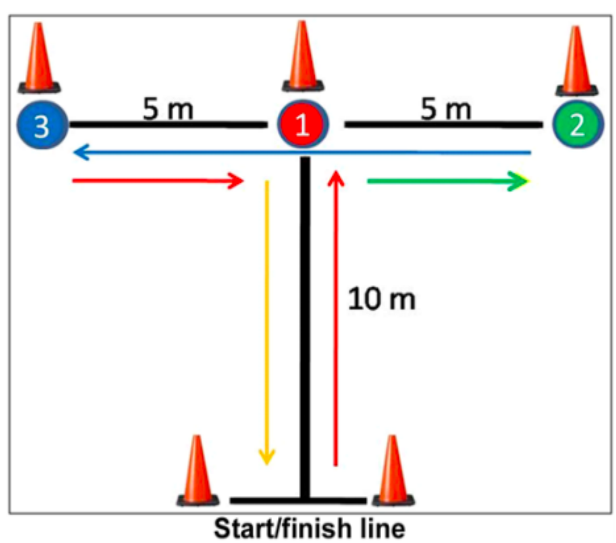

Figure 1. T test Agility

2024, Retos, 58, 1079-1086

Statistical analysis

SPSS software version 19 was used to analyze statistical data. The collected data were distributed using analytical methods such as Kolmogorov–Smirnov and Shapiro–Wilk tests. Therefore, parametric analysis was used in this study. To show the mean±SD of data, descriptive statistics were presented. To analyze the effect of the training program, Paired sample t-test, ANCOVA, and Quade Nonparametric Analysis of Covariance were performed. All the tests in this study were done at the significance level of $P < 0.05$. We use the SPSS.

Results

After using Kolmogorov–Smirnov test to analyze the data distribution, to assess the effect of the program training, paired sample t-test and ANCOVA were applied. According to the results of paired sample t-test and ANCOVA, the experimental group performed significantly better in all the tests in this study. In addition, paired sample t-test illustrated that, in the control group, there was a significant difference between the pre and post-test in Cooper and Squat test. However, based on ANCOVA analysis, there was a significant difference between the experimental and control group in all tests (Cooper, Squat, 60-meter dash, and t-test).

Table 2.
Illustrates the descriptive measures of subject demographic information.

Groups	Control Group	Experimental Group	All
Age	18.05±0.88	17.25±0.91	17.65±0.97
Gender	Male	Male	Male
Height	176.95±5.31	178.15±5.90	177.55±5.57
Weight	73.20±5.63	75.05±4.28	74.12±5.02

Data means ± SD. Both experimental and control groups were given typical exercises. But experimental group besides the typical football exercises; they received the training program of this study.

Table 3.
Statistical results of the different variables.

	Mean	SD	Mean	t	P value
Pre Cooper test (CG)	2740.00	264.37	27.41	-2.37	0.028
Post Cooper test (CG)	2805.00	223.54			
Pre-Squat test (CG)	73.45	8.36	0.65	-2.06	0.053
Post Squat test (CG)	74.80	7.23			
Pre-60-meter (CG)	7.99	0.55	0.12	0.57	0.572
Post 60-meter (CG)	7.92	0.62			
Pre-T test (CG)	9.80	0.75	0.127	0.416	0.682
Post T test (CG)	9.75	0.80			
Pre Cooper test (TG)	2772.50	205.50	38.26	-8.69	0.001
Post Cooper test (TG)	3105.00	139.45			
Pre-Squat test (TG)	70.40	7.73	0.82	-11.04	0.001
Post Squat test (TG)	79.50	6.58			
Pre-60-meter (TG)	7.47	0.56	0.05	3.58	0.002
Post 60-meter (TG)	7.25	0.39			
Pre-T test (TG)	9.43	0.60	0.058	4.43	0.001
Post T test (TG)	9.18	0.43			

The variables of the study were assessed from control group (CG) and experimental or training group (TG). This table Mean ± SD of all variables.

The paired sample test showed no statistically significant difference between the pre and post-test 60-meter dash and t-test. As reported by the results of ANCOVA, there is a significant difference between the control and experimental groups, and the experimental group showed better improvement in all variables. However, according to the table (Table 5) and figure (Figure 2) below, the assumption of linear regression slope still needs to be met. Therefore, Quade Nonparametric Analysis of Covariance was utilized.

Table 4.
Univariate Tests.

Source	Sum of Squares	df	Mean Square	F	Sig.
Cooper test	780748.50	1	780748.50	55.43	0.001
Squat test	484.34	1	484.34	58.80	0.001
60 meters	0.925	1	0.925	6.224	0.017
T test agility	0.837	1	0.837	4.97	0.032

Sig shows the difference between the two groups. Control and experimental groups.

Table 5.
Linear regression slope.

Source	Type III Sum of Squares	df	Mean square	F	Sig
Cooper test	1656237.57	2	828118.78	54.44	0.001
Squat	1720.77	2	860.38	100.00	0.001
60 Meter	9.11	2	4.55	30.64	0.001
T test agility	13.04	2	6.52	38.91	0.001

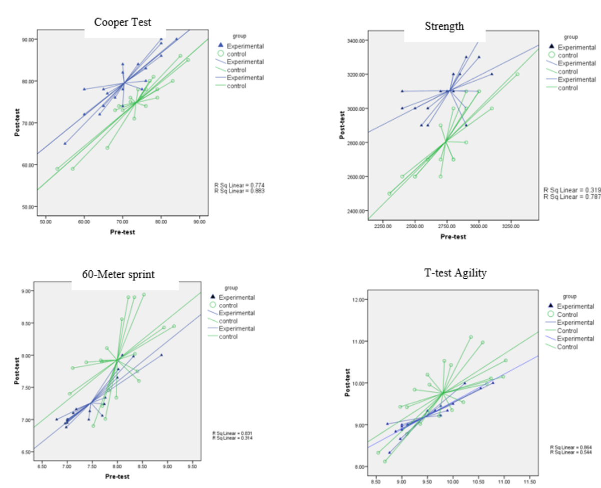

Figure 2.

Figure 2 shows scatter plots of all variables. It illustrates the relationship between the pre-test and post-test records of both groups. Also, the assumption of linear regression slope needs to be met. Table 6 shows the results of the Quade Nonparametric Analysis of Covariance.

Table 6.
Results of the Quade Nonparametric Covariance.

Source	F	DFH	DFE	Sig
Cooper test	41.74	1	38	0.001
Squat	32.90	1	38	0.001
60 Meter	4.13	1	38	0.049
T test agility	7.55	1	38	0.009

As the results of Quade Nonparametric Analysis of Covariance show, as the same as ANCOVA, the effect of the program training is significant for all variables.

Discussion

This study investigates the effect of eccentric and interval exercises on young amateur football players' strength, agility, speed, and cardio strength. Based on the results, eccentric and interval exercises can improve the cardiovascular system, speed, agility, and strength. The advantages of eccentric exercises on muscles and blood variables were well studied but comparing these types of exercise with typical field-related exercises should be investigated more.

Bhavna and Sandhu reported that in comparison with concentric exercises, eccentric resistance exercise showed significantly less Systolic Blood Pressure, Mean Arterial Pressure, pulmonary responses of Heart rate, and peak cardiovascular (Bhavna & Sandhu, 2010). Also, Overend et al. demonstrated that the body tolerates less mean arterial pressure and maximum heart rate with eccentric exercises (Overend, Cunningham, Kramer, Lefcoe, & Paterson, 1992). This study showed that resistance training focused on eccentric and interval exercises can significantly improve the cardiovascular system more than typical exercises in young football players. However, typical football exercises could affect the cardiovascular system statistically. The program training contains not only eccentric exercises but aerobic interval training in which a load of all exercises changes every four weeks. Moreover, the time of this training program was long enough to change structure or physiology. The responses of cardiovascular to exercises have been studied for decades. In most of them, it has been shown that submaximal exercises can reduce VO2 at the same workload because of improved efficiency. For instance, Mora-Rodriguez et al. reported that aerobic interval training could reduce the heart rate and increase stroke volume. In their study, while they increased workload to achieve the same level of VO2, they observed a reduction in heart rate (3%) and increased stroke volume (10%) (Mora-Rodriguez et al., 2017). increased stroke volume mainly attributed to increased end-diastolic volume as the result of increased left ventricular chamber size, plasma volume expansion, increased heart compliance, and faster diastolic filling rates (Carrick-Ranson et al., 2020; Esfandiari, Sasson, & Goodman, 2014; Khortabi, Suarez, Rezavandzayeri, & Carral, 2023).

Tjønna et al. reported that "aerobic interval training was superior to continue aerobic training in increasing endothelial function (9% versus 5%) insulin signaling in fat and skeletal muscle, skeletal muscle biogenesis, and excitation-contraction coupling and in reducing blood glucose and lipogenesis in adipose tissue" (Tjønna et al., 2008). Also, from the respiratory system and cardiovascular system point of view, Tieh-cheng Fu et al. compared the two methods of aerobic interval and continuous aerobic training. According to the results of their study, aerobic interval training can increase oxygen uptake efficiency slope (OUES) and lower VE-VCO2 slope more than continuous aerobic training. Furthermore, aerobic interval training, not continuing aerobic training, could boost cardiac output (Fu et al., 2013).

Metabolic adaptation to eccentric resistance exercises (for endurance) has not been completely understood. Some studies indicated that eccentric exercises do not induce adaptations in peak aerobic power and mitochondrial function. The relatively low exercise training metabolic stimulus can be the explanation for the lack of adaptive responses to eccentric exercises (for endurance) (Touron, Costes, Coudeyre, Perrault, & Richard, 2021). It can be said that the aerobic interval exercises in the present program training could fill the gap and compensate for this lack of adaptive response. Considering the results of the previous studies, it can be concluded that because of aerobic interval training and its mentioned superiority over other types of aerobic training, the program training of the present study could affect more than typical football exercises. Generally, regular exercise training contains aerobic exercises, which, based on the present research results, typical football exercises could be practical significantly on the cardiovascular system.

Some researchers have shown that the muscle fibers remain unchanged in eccentric exercises. Therefore, they assumed that improvement in muscle strength following eccentric exercises is more likely due to neuronal coordinative factors (Bhavna & Sandhu, 2010). However, many studies approved of architectural changes. The addition of sarcomeres in series increases muscle fiber length resulting in an increased maximal shortening velocity of the muscle. This adaptation acts as a protective mechanism from future bouts of eccentric contraction muscle soreness and damage. This increase in fiber length is because of shifting in the length-tension relationship (Faller, Bonneau, Wooten, & Jayaseelan, 2021). Steiner et al. stated that in a higher rate work up to 3-5 times for eccentric exercises (in comparison with concentric exercises), the rated perceived exertion (RPEs) is similar (Bhavna & Sandhu, 2010).

The present study results are consistent with previous studies investigating the effect of eccentric training on strength, agility or change of direction, and speed. For example, Lockie et al. examine the effect of an afforded eccentric muscle action training program with speed and agility training elements. The subjects of this study were recreationally trained team sport athletes. To examine agility, a T-test was performed. After six weeks of training, the results showed significant improvement in agility and speed (Lockie, Schultz, Callaghan, & Jeffriess, 2014). Likewise, according to Hoyo et al.'s study, 10-week strength training with accentuated eccentric muscle actions affect significant change of direction speed kinetics. Cross-over maneuvers and side-step cutting maneuvers were performed to examine the change of direction speed. The subjects were young soccer players aged 17 years (de Hoyo et al., 2016). Similarly, the effect of 11-week strength training with eccentric muscle actions and additional whole-body vibration versus conventional combined training that contains wright-loaded exercises, linear speed, and plyometric on change of direction in elite young soccer players aged 17 years. The variable of change of direction was measured by the V cut test. According to the results of this study, the program training (eccentric exercises) combined with vibration stimuli could improve change of direction speed performance significantly more than conventional training (Tous-Fajardo, Gonzalo-Skok, Arjol-Serrano, & Tesch, 2016).

At the early phase of the increase of muscle strength, neural adaptation is involved (Anwer et al., 2021); but hypertrophy, after four weeks, becomes the dominant factor for the increase of muscle strength (Moritani & Devries, 1980). The program training of this study was long enough to increase muscle strength through hypertrophy. The neural phase of strength gain represents the magnitude of the efferent neural output of active muscle fibers. Also, increasing in firing rate in individual motor units is another cause of strength gain in the neural phase (Anwer et al., 2021). Muscle length is an essential element in producing force and muscle strength gain. Eccentric exercises can generate greater forces through the stretch; it can cause the recoiling of passive structures such as titin (Herzog, 2014). Benford et al. concluded that eccentric exercises cause greater mid-point and distal end changes. Concentric contraction can lead to more significant changes at the mid-point of the muscle, and a greater fascicle angle (Benford, Hughes, Waldron, & Theis, 2021). Franchi et a. Argued that inflammatory responses and muscle damage usually could be observed in eccentric exercises, blunts, e hypertrophic responses to eccentric exercises training. However, indeed eccentric contraction produces a more significant mechanical stimulus (Franchi et al., 2015). Our strength data revealed that although there was a significant difference between the pre and post-test in the control group, the experimental group showed statistically significantly better improvement. Most of the training loads in this study were 75-90% 1RM with 8 to 15 rep. One explanation of this outcome is that eccentric exercise can make muscle reach its highest activation level. Sonay Guruhan et al. reported that nordic hamstring exercise leads to higher muscle activation in comparison with other types of exercises (Guruhan, Kafa, Ecemis, & Guzel, 2021). Schoenfeld et al analyzed 21 studies and concluded that maximal strength benefits are obtained from the use of heavy loads (Schoenfeld, Grgic, Ogborn, & Krieger, 2017). Heavy loads are associated with more muscle activation, which means higher muscle activation is associated with higher muscle strength gain. The program training of the analyzed studies lasted a minimum of 6 weeks. It is well-approved that eccentric exercises can improve strength. As reported by previous studies, there is a highly significant correlation between strength and speed (Sammito, Gundlach, & Böckelmann, 2016). Therefore, with the increase in strength level, we would observe an increase in speed. Hammami et al. reported that eccentric training could significantly improve speed, agility, and power. They measured 10m and 30m sprint speeds as a test to assess speed in subjects (Hammami, Duncan, Nebigh, Werfelli, & Rebai, 2022). The results of this study are consistent with the present study, which showed that eccentric exercise could improve speed significantly. However, a study argued that some beneficial adaptations following eccentric exercises are not attributed to eccentric exercises. Instead, they are primarily related to other factors, such as exercise intensity. This study was done by Hooren et al. They stated that "high-intensity isometric exercises in which the series elastic element stretches and recoils may be equally or even more effective at conditioning the hamstrings for high-speed running since they also avoid some of the negative side effects associated with eccentric training." (Van Hooren & Bosch, 2017). The negative points they mentioned primarily argued on hamstring and Nordic hamstring exercises. Some of the negative points they mentioned are 1- it is too difficult for untrained individuals to do Nordic hamstring exercises in a full range of motion, 2- being difficult to adjust the load, 3- Specificity of adaptation at an intermuscular level (Van Hooren & Bosch, 2017). Our program training in this study was wider than one specific exercise. Instead, it contains many eccentric exercises involving many movements and muscles throughout the body.

Conclusion

In this research, according to the Focus on eccentric concentration and interval training after a month of general preparation period, it was proved that eccentric concentration has a significant effect on the speed, agility, strength, and cardiovascular capacity of young and elite soccer players.

Conflicts of interest

The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the paper.

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