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Effect of Different Strength Training Modalities on Maximal Strength and Power in Semi-Professional Football Players

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ABSTRACT

The study provides an innovative perspective on comparing two training modalities of strength training to evaluate the effectiveness in enhancing maximal strength and power of lower limb strength. Our study aimed to examine the effects of eccentric and concentric strength training on the development of maximal lower-limb strength and power in semi-professional football players. The study involved 28 players (age 21.7 ± 2.1 years, body height 180.1 ± 4.6 cm, body weight 75.9 ± 7.2 kg) divided into eccentric (ECC), concentric (CON), and control (CONTR) groups. The eight-week training intervention targeted the knee extensors and flexors. Knee flexor strength was developed using the lying leg curl machine, and knee extensor strength using the seated leg extension machine. The concentric group trained with the maximal effort method, while the eccentric group applied the 2/1 eccentric method. The results showed significant improvements in maximal strength of the extensors (CON +19.4%, $p < 0.001$, $d = 1$; ECC +19.42%, $p < 0.001$, $d = 0.89$) and improvements, but not significant ($p = 0.11$, $\eta p^2 = 0.16$), of the flexors (CON +12.81%, ECC +12.14%) of the knee joint. No significant improvement in power ($p = 0.11$, $\eta p^2 = 0.16$) was observed, measured by standing broad jump performance. These findings highlight the specificity of training adaptations, where improvements in maximal strength may not directly translate into enhanced power. The study emphasizes the importance of both training modalities due to their sport-specific benefits for football, such as acceleration, changing direction, positive effects on muscle architecture, and injury prevention.

Keywords: intervention, concentric and eccentric strength, performance testing, team sports.

INTRODUCTION

Football is considered an exceptionally complex sport that places high demands on various physical abilities, such as aerobic and anaerobic fitness, speed, strength, and agility (Sporiš et al., 2011). These physical components are essential to managing approximately 1,300 movement changes during a single match (Chaouachi et al., 2012). During gameplay, the lower limbs must generate significant force to enable movements such as acceleration, deceleration, jumps, landings, rotational movements, and rapid directional changes (Maly et al., 2014). Muscle strength plays a key role not only in maximizing athletic performance but also in injury prevention. Knee extensors are crucial for sprinting, jumping, and kicking, while knee flexors contribute to knee flexion, improving athletic performance and stabilizing the knee joint (Lehance et al., 2009).

Football requires frequent and rapid directional changes, placing great demands on deceleration ability. Eccentric training is ideal for developing this ability, as it allows players to enhance movement control during deceleration and thereby perform directional changes more efficiently. It is assumed that athletes who regularly engage in eccentric training exhibit a greater ability to slow down movements and subsequently change direction more quickly (Spiteri et al., 2014). Eccentric training provides a potent stimulus for improving the mechanical function of muscles and morphological and architectural adaptations of the muscle-tendon unit. Additionally, incorporating eccentric loads not limited by concentric strength appears to be superior to traditional resistance training in improving variables related to strength, power, and speed performance (Douglas et al., 2017). Eccentric training imposes more significant mechanical stress on muscles, promoting hypertrophy and increasing maximal strength. Subsequent adaptations contribute to enhanced power, manifesting as the ability to perform movements with greater force and speed (Suchomel et al., 2019). Since hamstring injuries are among the most common in football (Paul & Nassis, 2015; Darragi et al., 2024), incorporating eccentric training can be highly beneficial. The study by Al Attar et al. (2017) demonstrated that regular implementation of eccentric exercises, such as the Nordic hamstring exercise, reduces injury rates and supports long-term performance sustainability in players.

In contrast to eccentric movements, concentric movements are defined as the dynamic shortening of sarcomeres. This type of training protocol also leads to muscle hypertrophy (Schoenfeld et al., 2017). Proper development of strength capabilities results in increased maximal strength, which is generally associated with improved relative strength. A significant relationship has been observed between 1RM values, acceleration, and movement speed. Thus, results from jump tests correlate with maximal strength. The relationship between maximal strength and performance can be confirmed through jump tests. By increasing the strength of muscle contractions in specific muscles or muscle groups, acceleration in situations critical to football performance, such as deceleration, or direction changes, can be improved (Hoff & Helgerud, 2004).

Strength progression can be achieved using eccentric or concentric strength training forms. In the study by Cormie et al. (2010), a 10-week lower-limb strength intervention involving three training sessions per week demonstrated statistically significant changes in vertical jump height. Similarly, Wong et al. (2010) observed improvements in vertical jump height after a 12-week strength and power training program involving 28 young male football players. Moore et al. (2005) conducted a study where the participants underwent a 12-week strength intervention, referred to in the study as Olympic-style lifting, completing 33 training sessions. This program resulted in a 9% improvement in vertical jump performance.

The progressive combination of eccentric and concentric actions forms the most common type of muscle function, called the stretch-shortening cycle (Cormie et al., 2011). Strength training using concentric or eccentric methods should be integral to football players' training plans. These exercises provide benefits crucial for enhancing performance, preventing injuries, and overall physical preparation. Integrating eccentric and concentric exercises into training programs can improve power, injury resilience, and prepare players for demanding movements and scenarios typical of football matches. This study provides an innovative perspective on comparing two types of strength training interventions aimed at developing knee flexors and extensors to evaluate their effectiveness in enhancing maximal strength and power of lower limb strength. This approach is unique in its focused analysis of distinct physiological and biomechanical adaptations, which can have a direct impact on performance and injury prevention in sports. Our study aimed to compare the two types of strength development (eccentric and concentric) for knee flexors and extensors and their impact on the changes in strength and power of the lower limbs through an intervention program. Therefore, we hypothesize that eccentric training will lead to greater improvements in maximal strength and power of the lower limbs compared to concentric training.

METHODS

Participants

The study involved 28 semi-professional football players (3rd to 5th league). Their average age was 21.7 ± 2.1 years, average body height was 180.1 ± 4.6 cm, and average body weight was 75.9 ± 7.2 kg. Goalkeepers were deliberately excluded from the study due to the specific nature of their playing role. A prerequisite for participation was that players had at least 10 years of active football experience and, during the study period, participated in three training sessions per week and one match with their clubs. Players who were injured or in the recovery phase were excluded from the selection. Players were randomly assigned numbers at the beginning of the study. A random number generator was then used to randomly allocate the required number of participants to each group. Overall, 33 players participated in this study. For objective reasons (illness, missing sessions, injury, transfer to another club, etc.) 28 players completed the study. The concentric group (CON) consisted of 10 players, the eccentric group (ECC) had 11 players, and the control group (CONTR) included 7 players (who did not undergo the strength intervention). Only data from players who participated in all training sessions were included in the results. Before the study commenced, all participants were informed about its content and provided signed informed consent. The study was conducted in accordance with the Declaration of Helsinki and was approved by the local Research Ethics Committee (EKV-2016-096).

Procedures

We selected the standing broad jump test to assess the lower limbs' power. Due to its simplicity, this test is considered a reliable tool for detecting the level of lower-limb power (Marin-Jimenez et al., 2024). Before testing, the players went through a general warm-up consisting of jogging, running, dynamic stretching, joint mobilization, few sprints and familiarization attempts of broad jump. The jump length was measured from the take-off line to the landing point of the heel closest to the take-off line. A demonstration with a detailed explanation of the test procedure was provided. Players were allowed to use their upper limbs during the standing broad jump. In the case of an invalid attempt, the jump was annulled, and a new attempt was required. Three attempts were performed, with a 2-minute rest interval between them. Only the best attempt was considered. The same footwear was used for pre- and post-test.

We selected the following exercises to determine the maximal strength (1RM) of the knee flexors and extensors. For knee flexors (1RM FLEX), we used the lying leg curl machine (Grün sport). For knee extensors (1RM EXT), we used the seated leg extension machine (Grün sport). The Baechle protocol (Baechle & Earle, 2008) was used to determine 1RM accurately (Figure 1). We selected a load estimated to allow 5 to 10 repetitions. After a 1-minute pause, the load was increased, and 3 to 5 repetitions were performed, followed by a 2-minute pause. The load was further increased, and 2 to 3 repetitions were performed. After a 3-minute pause, the load was increased again, and an attempt at 1RM was performed. If the repetition was successful, another 3-minute rest was taken before increasing the load again to approach the final 1RM value. If the 1RM attempt failed, a 3-minute pause followed, and the load was reduced.

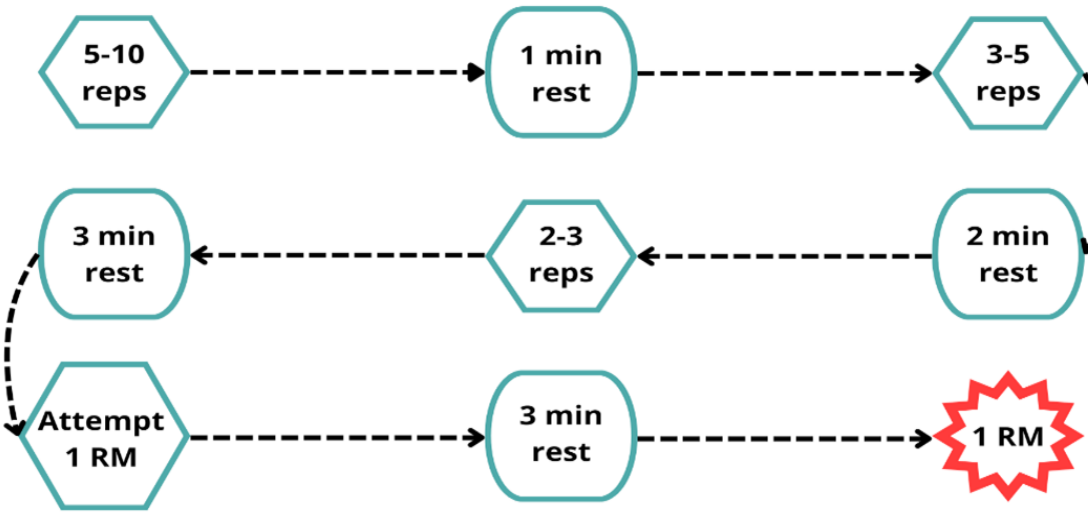

Figure 1 Baechle's protocol for 1RM (Baechle & Earle, 2008)

Intervention Program

We selected the following exercises in our intervention program, which focused on the maximal development of knee flexor and extensor strength. We used the lying leg curl machine to develop knee flexor strength. We used the seated leg extension machine to develop knee extensor strength. Compared to squats with a barbell, the advantage of these exercises was the reduced risk of injury and incorrect execution. Although these exercises were less technically demanding than squats, we implemented a two-week preparatory strength block prior to the intervention program, during which participants familiarized themselves with machine exercises. The concentric group utilized the maximal effort method during training, while the eccentric group applied the 2/1 eccentric method (two legs lifted the load, but only one controlled the lowering phase).

Our intervention program spanned eight weeks,with two training sessions per week. Strength training was performed at least 48 hours after a football match. Each exercise consisted of 5 sets of 5 repetitions (for the eccentric group, 5 repetitions were performed with the left leg and 5 with the right leg), with a 3-minute rest between sets. A standardized warm-up covering all necessary components was performed before each training session. Throughout the intervention program, both groups progressively increased the load to achieve the desired development of strength capabilities.

In the concentric group, participants trained with a resistance of 80% of 1RM during weeks 1 and 2. During weeks 3 to 5, the load was increased to 85% of 1RM; in weeks 6 to 8, it was raised to 90% of 1RM. In the eccentric group, participants trained with a resistance of 120% of 1RM during weeks 1 and 2 (in the eccentric group, the 1RM value always referred to the strength of one limb). The load was increased from 120% to 130% of 1RM during weeks 3 to 5 and further increased to 140% of 1RM during weeks 6 to 8.

Data analysis

Data are presented as mean ± standard deviation (SD). The Shapiro-Wilk test verified the normality of distribution, while Levene's test confirmed the homogeneity of variance. Factorial analysis of variance (ANOVA) with repeated measures was used to assess and compare the effects on strength and power variables, utilizing a 3 × 2 design (three groups: concentric, eccentric, and control; two time points: pre-test, post-test). When ANOVA detected significant differences, the Bonferroni post hoc test with correction was used for pairwise comparisons. Effect sizes (ES) were determined by partial eta squared (ηp^2), with values of 0.01, 0.06, and 0.14 indicating small, medium, and large effects, respectively. Cohen's d and 95% confidence intervals (95% CI) expressed within-group effect sizes for pre-to-post performance changes. Cohen's d was interpreted as trivial (< 0.2), small (0.2–0.5), medium (0.5–0.8), and large effect (> 0.8) (Cohen, 1988). A significance level was set for $p \leq 0.05$. All statistical tests were calculated using IBM SPSS Statistics 28 (IBM Corp., New York, USA).

RESULTS

All the results for pre- and post-testing in all groups are individually described in Table 1. In the 1RM extension test was significant interaction ($F2, 25 = 11.01$, $p < 0.001$, $\eta p^2 = 0.47$). Pairwise comparison showed a significant difference between the pre- and post-test of the concentric ($p < 0.001$, $d = 1$) and eccentric group ($p < 0.001$, $d = 0.89$). A significant difference was also found between the eccentric and control groups in the post-test ($p = 0.031$). Interactions were not significant in the 1RM flexion test and broad jump test. However, in the 1RM flexion test in the concentric and eccentric groups, the effect size was medium (d = 0.66 and d = 0.73, respectively). The percentage of changes in the performance of all groups is shown in Figure 2.

Table 1 Pre- and post-intervention testing results

Group	Pre-test	Post-test	Time		Group		Time × Group		ES (95% CI)
			p	ηp^2	p	ηp^2	p	ηp^2	
1RM EXT									
CON	75.5 ± 13.8	90.2 ± 15.4	<0.001	0.75	0.12	0.16	<0.001	0.47	1 (0.03; 1.88)
ECC	79.6 ± 14.3	95 ± 19.8							0.89 (-0.01; 1.73)
CONTR	71.8 ± 7.2	73.7 ± 6.5							0.28 (-0.79; 1.31)
1RM FLEX									
CON	70.3 ± 12	79.3 ± 15.2	<0.001	0.62	0.18	0.13	0.11	0.16	0.66 (-0.27; 1.52)
ECC	75.6 ± 13.2	84.8 ± 11.9							0.73 (-0.16; 1.57)
CONTR	67.9 ± 4.9	71.4 ± 6.7							0.6 (-0.51; 1.62)
Broad jump									
CON	232.6 ± 16.3	228 ± 19.9	0.65	0.01	0.99	0.001	0.11	0.16	-0.34 (-1.21; 0.56)
ECC	229.8 ± 21.2	233.4 ± 23.7							0.16 (-0.68; 0.99)
CONTR	229.6 ± 17.6	233.1 ± 18.6							0.03 (-1.02; 1.07)

Note: CON – concentric group; ECC – eccentric group; CONTR – control group; Time – difference between pre-test and post-test regardless of group; Group – difference between groups regardless pre-test and post-test; Time × Group – interaction effect taking into account two time points and three groups; p – level of statistical significance; ηp^2 – partial eta squared; ES – effect size; CI – confidence intervals

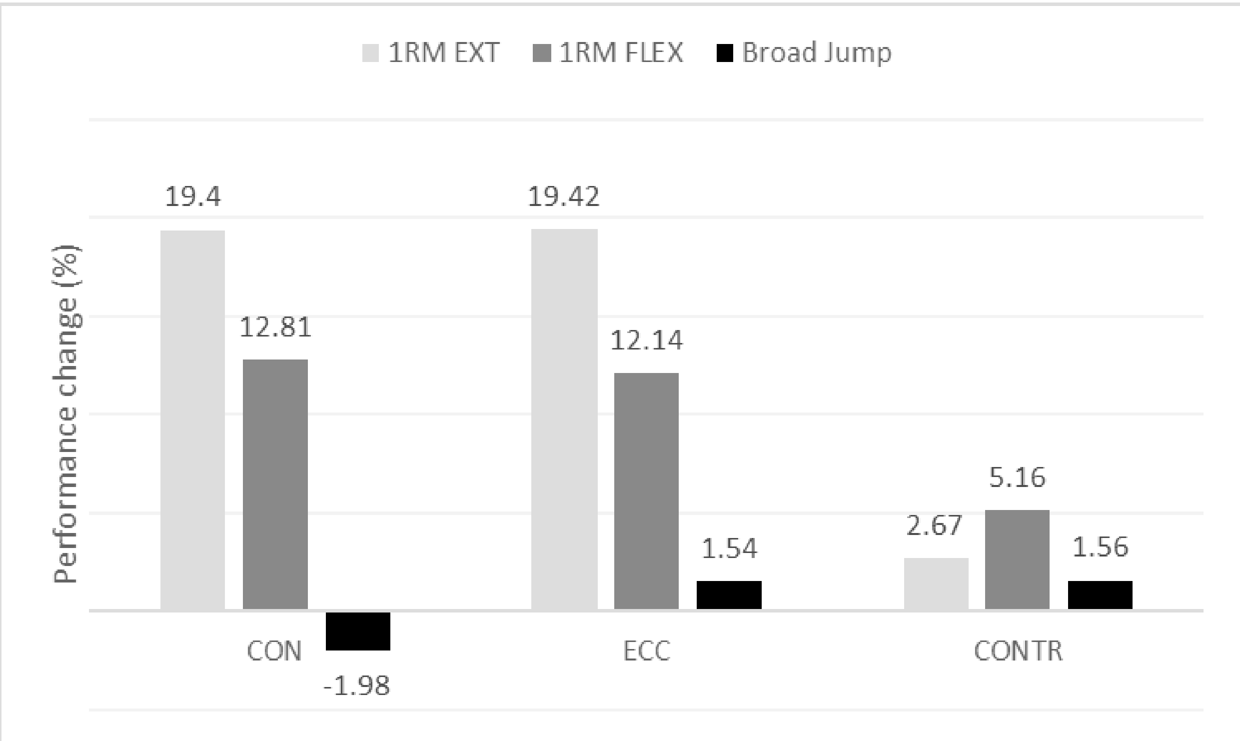

Figure 2 Percentage of changes in the performance of all groups

DISCUSSION

This study investigated the effects of eccentric and concentric strength training on changes in lower-limb strength and explosive abilities in semi-professional football players. Our results showed significant improvements in knee extensor and flexor strength in both the concentric and eccentric groups, demonstrating a substantial increase in the maximal strength of the knee flexors and extensors. On the other hand, lower-limb power (measured by the standing broad jump) did not show significant improvement in any of the examined groups. The significant improvement in the strength of knee extensors and flexors is essential for football performance, as these muscles play a critical role in kicking, knee stabilization, and generating force during directional changes. Eccentric training also showed minimal improvements in power. This change could be attributed to the higher mechanical load on muscle fibers, which triggers an intense anabolic response (Hedayatpour & Falla, 2015). Moreover, eccentric contractions promote the elongation of muscle fibers and improvements in their architectural parameters, enhancing their force-producing capability (Douglas et al., 2017). Concentric training also increased muscle strength; however, its effect on power did not reach significance. This finding is consistent with the literature, suggesting that eccentric contractions generate a greater training stimulus than concentric contractions (Roig et al., 2009). The control group demonstrated minimal changes without direct strength intervention, which may result from natural football training, as McKinlay et al. (2018) suggested. Minimal gains in maximal strength and power confirm that targeted intervention is required to achieve significant improvements in strength capabilities, even among trained athletes.

When comparing our results with other studies, we found that different forms of strength training led to changes in power. For instance, in the study by Cormie et al. (2010), a 10-week lower-limb strength intervention with three weekly training sessions resulted in statistically significant changes in vertical jump height. Wong et al. (2010) observed improvements in vertical jump height in 28 young male football players after a 12-week strength and power training program. Similarly, Moore et al. (2005) conducted a study where participants underwent a 12-week strength intervention (referred to as Olympic-style lifting) consisting of 33 training sessions. This program resulted in a 9% improvement in vertical jump height, equating to an increase of 4.23 cm. Bino and Murugavel (2024) also reported a significant increase in power, where 15 male athletes improved their standing broad jump by 31 cm using high-intensity resistance training.

Despite the significant improvement in the maximal strength of knee extensors and flexors in our study, power (measured by the standing broad jump) did not improve significantly. This finding highlights the specificity of training adaptations and the differences between maximal strength and the ability to generate power. Power requires rapid motor unit recruitment, the elasticity of muscle and tendon structures, and effective neuromuscular coordination, which may not be optimally developed through eccentric or concentric training alone (Cormie et al., 2011; McBride et al., 2002). Moreover, heavy-resistance training with high loads and slow concentric muscle action velocities primarily enhances maximal strength, targeting the high-force, low-velocity segment of the force-velocity curve. In contrast, power training, which incorporates lighter loads and faster muscle contractions, improves force production at higher velocities and increases the rate of force development (Sáez Sáez de Villarreal et al., 2011). Additionally, the lack of improvement in power may be attributed to the absence of specific plyometric training, which is considered essential for enhancing dynamic performance indicators such as jumping ability (Markovic & Mikulic, 2010). Therefore, it is advisable to focus not only on the development of maximal strength but also on the development of power, which is an integral component of athletic performance.

Our findings provide important insights into the effectiveness of eccentric and concentric training in semi-professional football players. Improving the maximal strength of knee extensors and flexors can be beneficial for training processes in football, where these muscles are essential for actions such as kicking, deceleration, and acceleration. Coaches should incorporate eccentric training into their training plans to increase maximal strength and reduce the potential risk of injuries often associated with knee joint overload. On the other hand, the lack of improvement in power suggests that strength training alone is insufficient for developing explosive capabilities. Future research should focus on combining strength training with plyometric training to achieve comprehensive improvements in power and speed-strength capabilities that are critical for football performance. Long-term studies are recommended to examine the effects of both training types with larger participant samples and employ a broader range of tests to assess power. Additionally, one of the main limitations of our study could be the small sample size in each group, which may have affected the statistical significance of the results. The post hoc analysis revealed the power of study sample $1 - \beta = 0.6$ with $\alpha = 0.05$ and $f = 0.25$. Furthermore, focusing on two isolated exercises (leg extension and leg curl) may limit the transfer of training effects to sport-specific movements. In the future, it would be beneficial to include more complex exercises such as squats, or lunges, which engage a larger number of muscle groups and are biomechanically closer to movements performed in football. Similarly, the use of the deadlift could be considered a suitable tool due to the similarity in joint angles between the deadlift and movements such as jumping (Malyszek et al., 2017).

With our findings, we aim to contribute to a better understanding of the effects of maximal strength training on changes in maximal strength and power of lower-limb in semi-professional athletes. Although we did not demonstrate a statistically significant increase in power, training programs designed based on our insights can support the development of maximal strength while reducing the risk of injuries, which is crucial for football players across all age categories and performance levels.

CONCLUSION

The present study examined the effects of eccentric and concentric strength training on maximal strength and power development in semi-professional football players. The results revealed significant improvements in maximal strength of knee extensors and improvement, but not significant, of knee flexors in both concentric and eccentric training groups. This enhancement underscores the critical role of these muscle groups in football performance, including kicking, braking, and direction changes. However, no statistically significant improvement in power, as measured by broad jump performance, was observed in either group.

The lack of improvement in power highlights the specificity of training adaptations and the distinct requirements for maximal versus explosive force production. Therefore, incorporating plyometric training alongside strength exercises is recommended to achieve comprehensive development of strength and power capabilities essential for football performance.

Future research should explore the long-term effects of combined training approaches on larger participant samples and include diverse performance metrics to better understand the interplay between training modalities and football-specific performance. Integrating complex, sport-specific exercises, could optimize training adaptations and transfer to real-world football activities. These findings provide a foundation for developing targeted training programs to support semi-professional football players' athletic and performance needs.

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