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Effects of 16-weeks of strength training on jump height and anthropometric variables in U19 semi-professional male soccer players

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Abstract

Purpose: The aim of our study was to examine the effect of 16 weeks of strength training on anthropometric characteristics and jump height in semi-professional male players after a pre-season period.

Methods: A parallel two-group, longitudinal (pre, post) design was used with physical tests performed before (preintervention) and after (postintervention) the 16-week intervention period. The soccer players were assigned and matched into two groups, an experimental group (EG) and a control group (CG), based on the team of which they were a part.

Results: A two-way ANOVA was performed with group and time as factors. The results of a two-way ANOVA revealed no time×group interaction for body composition or jump height. Nevertheless, a paired measures *t*-test of weight, fat mass, lean mass, and countermovement jump (CMJ) test metrics (pre-post) and group (CG and EG) showed an improvement in all measures ($p < 0.01$).

Discussion: The 16-week intervention program resulted in an improvement in the EG both at the level of body composition and in CMJ performance.

Conclusions: Despite the benefits of the 16-week intervention program, a combination of training methods that includes power, agility-coordination, speed, and strength can enhance such improvements. It is important to take this strength-specific capacity into account in training, due to the importance outlined in the sport of soccer both for its transfer to both linear and COD sprints and specific strength skills and mainly to vertical jump.

Keywords

Agility, association football, change of direction, coordination, resistance training, speed

Introduction

In soccer, jumping skill development assessed with the countermovement jump (CMJ) test is widely used to measure jumping power and strength in soccer players. The CMJ can still provide valuable information about an athletés explosive power and lower body strength. Likewise, these qualities can be important for soccer players when executing quick movements and changes of direction (COD) on the field. During COD hard and sharp braking is performed bilaterally, similar to that of CMJ runs. Indeed, explosive power in the lower body is necessary for soccer players to generate forceful movements when accelerating, decelerating, and changing direction also highlighting the importance of jump higher during aerial challenges.[1,2] Although CMJ assessment is not considered a manifestation of general strength of the soccer players, the relationship between lower body strength assessed with the CMJ and linear velocity and COD in soccer has been extensively investigated.[2–4] Therefore, increasing strength capacity can result in an increase in

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rapid force production of an impulse, which can have important implications for acceleration and deceleration in soccer players that is well known are abilities critical for success and both require the production of a large amount of force over short periods of time. In addition, relative impulse plays a key role in this work because linked the ratio of impulse to body mass.[1] For this reason, strength training will show improvement on lower-limb muscle power and can improve their relative impulse, allowing them to generate greater force relative to their body mass and move more efficiently on the field.[5]

Jumps are among the actions that have the greatest influence in the current game.[5] Players can perform more or fewer jumps depending on the position occupied on the playing field, varying between 1 and 36 jumps,[6] therefore improvement in jump height seems to be a parameter of performance in this type of actions. In this line of thought, it should be noted that maximum force presents a high correlation with performance in both vertical jump and sprint in elite soccer players.[7] So, strength training appears to be an important means for the improvement of jumping and performance in young elite soccer players.[8,9] In this respect, the above correlation could be explained by the study of Comfort et al., 2022[10] that showed underpinning biomechanics linked with early multi-joint force production, which could also give benefit of training with high loads to improve early force production, especially with participants with limited experience in this strength training. Regarding the improvement in sprint performance, also have a connection between CMJ height and soccer players' leg muscular strength and power measures,[11] showing larges improvements in both measures. Therefore, all improvements were linked with the variable resistance training[11] and anthropometrics characteristics of players.[12]

Anthropometric characteristics in particular and body composition in general, influence the sports performance of soccer players.[13] It is extremely important to monitor body fat levels in order to allow the players to move more efficiently and will lead to greater success in competition.[14,15] In fact, there is a complex interplay of factors that contribute to an athletés body mass, including their genetics, diet, training, regimen, and lifestyle. In this sense, while aerobic capacity and strength levels can certainly play a role in soccer players body composition, they are not the only factors that influence,[15] and could affect performance factors such as power, strength, speed, agility, and weight, and especially an increased risk of injury.[15,16] In this respect, the performance values mentioned above were biomechanical affected by the fatigue accumulated strongly increased mechanism of injurie associated with the competition.[17] Body composition assessment in soccer could determine athletic potential and the likelihood of success, in combination with technique and tactical, physical, functional, and psychosocial factors.[18,19] Different approaches can be used to assess and determine body composition. Among them is the five-way fractionation method, which divides the human body into skin mass, adipose mass, muscle mass, bone mass, and residual mass based on anthropometric measurements of body mass, skinfolds, body perimeters, and bone diameters.[20] These anthropometric characteristics and body composition fractionation methods have several advantages over other methods (it is a simple an inexpensive method, using standard measurement protocols, validated by the International Society of Advance in Kinanthropometry[21,22]) which is why they are increasingly being used in body composition studies of soccer players.[23–25]

The main purpose of this research was to examine the effect of 16 weeks of strength training on anthropometric characteristics and jump height in semi-professional male soccer players after a pre-season period. The main hypothesis of the present study was that 16 weeks physical training would improve their anthropometric characteristics, body composition, and jump height assessed with the CMJ test.

Methods

Experimental approach to the problem

The study was conducted between July and December 2021. Specifically, 16-weeks (4-weeks of pre-season and 12-weeks of in-season; Table 1). At the time of these observations, the soccer players had completed four months of training. A parallel two-group, longitudinal (pre, post) design was used with physical tests performed before (preintervention) and after (postintervention) the 16-week intervention period. The soccer players were assigned and matched into two groups, an experimental group (EG) and a control group (CG), based on the team of which they were a part. In order to investigate the effect of a 16-week strength training program on young soccer players, those from the CG were asked to maintain their training routines, while those from the EG modified their training sessions by introducing thirty minutes of strength training work 2 days a week before the start of the main session. Regarding the day of training, it was preceded by 48 h of absence of training/match (Tuesday and Thursday). The data collection was conducted at a gym adjacent to the soccer field in an indoor facility with an average temperature of 20–22° and 35–45% relative humidity.

Participants

A total of 42 U19 young, male soccer players from two semi-professional teams (21 in the CG (aged $= 17.48 \pm 1.21$) and 21 in the EG (aged $= 17.60 \pm 0.97$), from the Baleares region, Spain, were recruited from the city of Palma de Mallorca, which has a population ranging from 250,000 to 500,000 inhabitants according to the Spanish Government National Institute of Statistics (http://www.ine.es/; accessed on April 12, 2022). Concerning the sample size, the following equation was used: $Sample\ Size = Z2 \times (p) \times (1 - p)/C2$, where Z = confidence level (95%); $p = 0.05$ and $C =$ margin of error 0.05. In this

Table 1. Timeline of this study.

	2021																		
		Pre-season							In-Season										
Months	July				September				October				November				December		
Week		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16		
Experimental Group	Pre									Strength training								Post	
Control Group		Pre									Standard training								Post

sense, a minimum sample size of 16 participants was required for a power level of .80 as determined by a prior power analysis based on previous study, to detect small-to medium sized effect. These players trained four times a week (90 min per session) and played one match a week. The training sessions were based on technical and tactical content development (70% of training time), technical skill improvement (10% of training time), and general improvements in physical condition (20% of training time). Generally, training sessions comprised a warm-up, main part, and cooldown.

The eligibility criteria for selecting the participants were (i) reported normal vision and no history of any neuropsychological impairments that could affect the results of the experiment, (ii) being an active player in the federated team, (iii) not presenting any injuries during the previous 2 months, (iv) giving their consent, and (v) participating in all the sessions during the study period. Prior to the day of data collection, players were requested not to take supplementation, and to maintain regular sleep and dietary habits. The participants' parents obtained information about the main aims of the investigation and signed an informed consent form. All the soccer players in this study were treated according to the American Psychological Association (APA) guidelines, which ensure the anonymity of participants' responses. ll the soccer players in this study were treated according to the American Psychological Association (APA) guidelines, which ensure the anonymity of participants' responses. The study was conducted in accordance with the ethical principles of the Helsinki Declaration for human research and was approved by the Research Ethics Committee of the Pontifical University of Comillas (Dictamen 2021/89) and the Ethics Committee of the University of Granada (Number 471/CEIH/2018).

Procedure

Preintervention. First, the team staff was informed about the objectives of the study, and the research team ensured that the parents or guardians signed their informed consent after having received details of the possible benefits and risks of the study. Subsequently, the research team studied and planned the structure of training together with the coaches and physical trainers and both teams.

Secondly, the soccer players performed the tests following the same order, and with a minimum of 3 min rest between tests. The anthropometry and CMJ tests were performed in a gym adjacent to the soccer field with an average temperature of 20–22° and 35–45% relative humidity (stable temperature of 21°C and relative humidity of 51%). Subsequently, the Yo-Yo intermittent recovery test - Level 1 (YYIRT1) was performed. This test only was developed in pretest on synthetic turf with a mean temperature of 18.2 ± 2.4°C and relative humidity of 68 ± 5% in both moments of assessment. The maximal oxygen uptake (VO_2max in mL/min/kg) was estimated using the following equation: $VO_2max = \text{final distance (m)} \times 0.0084 + 36.4$.

In addition, no rainy conditions occurred in the two moments of assessment, and the tests were performed at the same time of day (6:30 p.m.–8:30 p.m.). Subsequently, the CG staff were instructed to maintain their training routines and the EG staff were instructed about the coordination intervention program in their warm-up routines. Every training session and test was monitored by one main researcher and was directed by the physical training coaches responsible for the teams, who were specially trained for accurate and reliable data recording.

Intervention. The U19 soccer players completed a 16-week strength training program, which was designed individually for the EG and supervised by the main researcher and staff team for this group, considering the capabilities that they worked on for each weekly match. This program followed the guidelines, protocol and method created by Turner and Stewart[26] (see Figures 1 and 2).

Postintervention. After 10 weeks, the CG and EG were evaluated at the same time of day as in the preintervention session (6:30 p.m.–8:30 p.m.), in a similar space and at a similar time with the same humidity conditions. Everything was the same as in the preintervention session except that the Yo-Yo intermittent recovery test was not performed. The soccer players in the CG were also given an opportunity to perform the same program as the experimental group after the study ended.

Measures and instruments

Anthropometry. Anthropometric measurements were taken at the two moments of assessment at [Pre intervention (July) and Post intervention (December)] at the same time and on the same day of the week. The height was measured using a stadiometer (SECA 213, Birmingham, UK) to the nearest 0.1 cm, and players were asked to remove their shoes and other accessories that could influence the assessment. The variables weight, fat mass, and lean mass were analyzed with Bioelectrical Impedance Analysis method (BIA) using a TANITA® (MC-980MA PLUS, Arlington Heights, IL, United States). Players also had to be in a vertical and immobile position, with arms extended along the body, and looking straight ahead in an upright position. For each measure, only one measurement was collected.

Countermovement jump test. The CMJ test was evaluated using the Chronojump-Boscosystem® (Barcelona, Spain) developed by De Blas et al.[27] which revealed intraclass correlation test levels between 0.821 and 0.949 for measuring jump height and subsequently calculating the jump height. This system was connected to a MacBook Pro (macOS Sur 11.1). The values were analyzed with a chronopic and recorded by Chronojump version 2.0.2. After a warm-up, participants performed the CMJ test three times on a contact platform, with 20 s of recovery between attempts to minimize the effect of fatigue. The best jump (in cm) was considered as the final outcome. To avoid undesired effects by performing different jumping strategies, previous instructions were given to avoid mistakes. In this sense, they were instructed to jump as high as possible after reaching a knee angle of ∼90o. Participants were also instructed to keep their hands on their hips during the CMJ and to land with their legs extended with maximal foot plantar flexion. If any of these requirements were not met, the trial was repeated.

Statistical analyses

Data were analyzed using Statistica software (version 13.1; Statsoft, Inc., Tulsa, OK, USA) and the significance level was set at $p < 0.05$. Normal distribution and homogeneity tests (Kolmogorov–Smirnov and Levene's, respectively) were conducted on all metrics. The influence of the moment (pre and post) and the group (CG and EG) was analyzed using two-way ANOVA after checking the normality and homogeneity assumptions.[28] A paired sample *t*-test was used for determining differences as a repeated measures analysis (pre and post). Cohen's d was the effect size indicator. To interpret the magnitude of the effect size, we adopted the following criteria: $d \leq 0.20$, small; $d \leq 0.50$, medium; and $d \leq 0.80$, large. The effect size was presented as η_p^2 for a two-way ANOVA test and interpreted using the follow criteria: minimum effect ($\eta_p^2 \leq 0.02$), moderate effect ($0.02 < \eta_p^2 \leq 0.09$), and strong effect ($\eta_p^2 > 0.09$).[29]

Results

Firstly, a two-way ANOVA test was performed with group and moment as factors. There is no interaction in the body composition variables or in the jump test with moment*group. However, it has been observed that separately, both factors have high effects on the dependent variable. So, the paired measures *t*-test of weight, fat mass, lean mass, and CMJ test metrics according to the moment (pre- and post-tests) and the assessed group (CG and EG) are shown in Table 2 and Figure 3. There are some differences in all metrics. In EG, participants increased their weight, lean mass, and the height of the CMJ test, and decreased their fat mass ($p < 0.01$). The improvement in CMJ test was greater in EG than CG and the fat mass was lower in EG than CG after 16 weeks ($p < 0.05$).

Discussion

The within-group analysis revealed that the experimental group significantly increased body mass and lean mass, while significantly decreasing body fat percentage. In the case of the control group, no changes occurred in body composition. Between-group changes revealed significant increases in lean mass and significant decreases in body fat percentage favoring the experimental group. Additionally, the experimental group

Figure 1. Description of strength training for pre-season. Mesocycle with a duration of 6 weeks.

significantly improved CMJ height after the intervention, while the control group did not. Between-group differences were found, favoring the experimental group.

Our research confirmed that the strength-based training (which consisted of strength-endurance and strength-speed targets)[26] was beneficial for improving CMJ height, while

Figure 2. Description of strength training for in-season. Mesocycle with a duration of 10 weeks.

no significant variations were found in the control group. The between-group analysis emphasizes the benefits of strength-based training for youth soccer players. This evidence is in line with previous studies which compared strength-based training with control groups on youth soccer players' CMJ performance[30,31] that an important relationship p with mechanical term on soccer.[32] The benefits of strength training for youth athletes are well

Table 2. Performance variables before (pretest) and after (posttest) the intervention period (mean ± SD).

	Control Group ($n = 21$)				Experimental Group ($n = 21$)			
	Pretest	Posttest	%	Paired *t*-test (*p*)	Pretest	Posttest	%	Paired *t*-test (*p*)
Anthropometric measures								
Height (cm)	173.90 ± 5.07	175.05 ± 4.64	0.66 ± 0.69	$p = 0.001$ $d = -0.23$	175.70 ± 5.95	176.75 ± 5.69	0.62 ± 0.40	$p = 0.001$ $d = -0.18$
Weight (kg)	66.98 ± 8.10	66.17 ± 7.09	−1.14 ± 2.44	$p = 0.06$ $d = 0.10$	66.41 ± 6.93	69.05 ± 6.55	3.90 ± 2.00	$p = 0.001$ $d = -0.39$
Body Fat (%)	13.58 ± 2.46	13.64 ± 2.42	0.31 ± 6.57	$p = 0.74$ $d = -0.02$	13.80 ± 1.89	12.40 ± 1.98	−11.79 ± 7.7	$p = 0.001$ $d = 0.71$
Lean Mass (kg)	55.53 ± 3.96	55.52 ± 3.48	0.00 ± 2.57	$p = 0.97$ $d = 0.01$	55.67 ± 2.96	58.13 ± 2.69	4.18 ± 2.93	$p = 0.001$ $d = -0.86$
Yo-Yo intermittent recovery test-Level 1								
VO_2max (ml/kg/min)	52.56 ± 2.21	–	–	–	51.91 ± 2.69	–	–	–
Countermovement jump								
CMJ (cm)	35.83 ± 3.54	36.48 ± 3.61	1.68 ± 4.17	$p = 0.07$ $d = -0.18$	36.80 ± 3.65	38.67 ± 3.78	4.97 ± 6.42	$p = 0.001$ $d = -0.50$

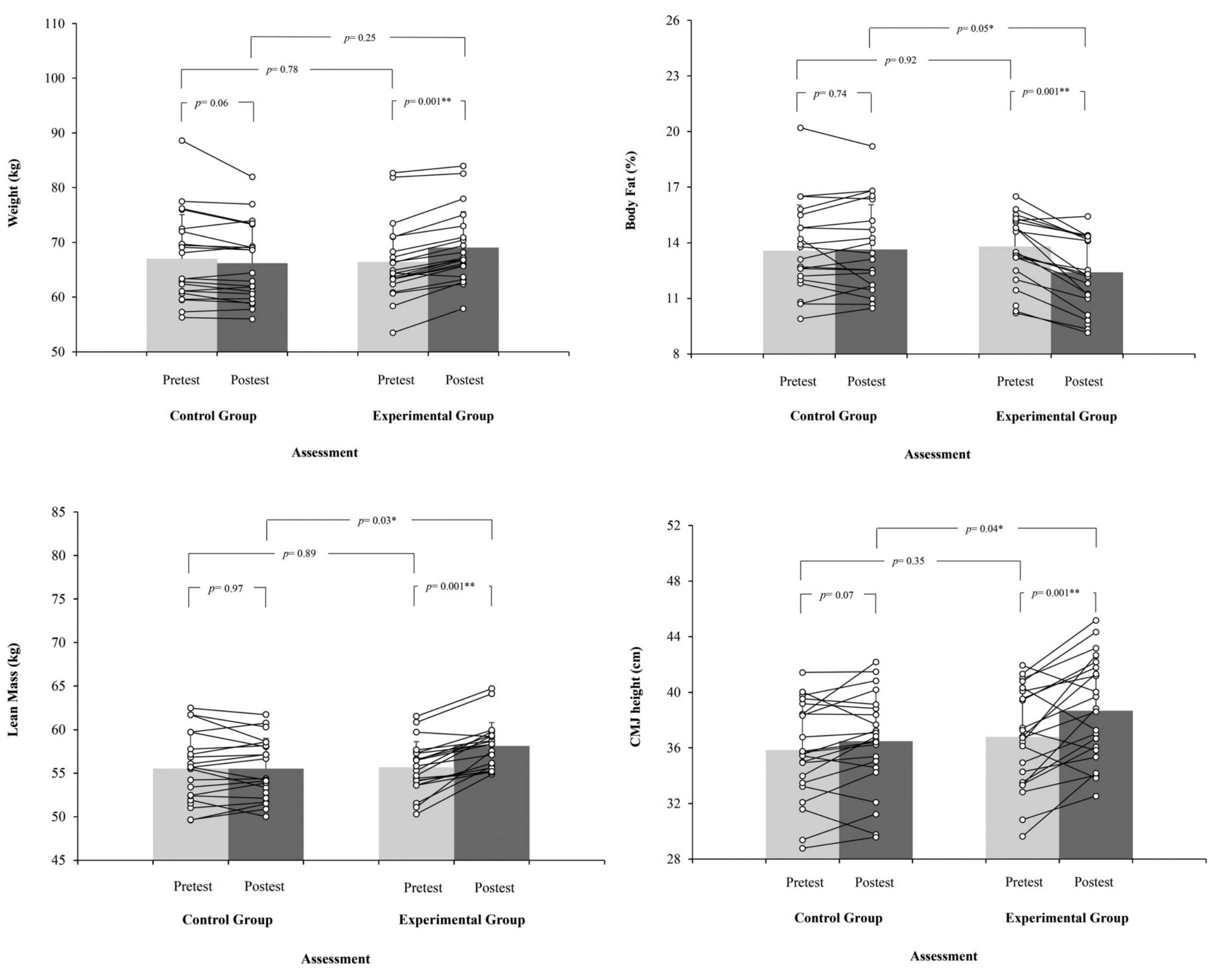

Figure 3. Pre- and post-tests in CG and EG of body composition and CMJ test.

established, in particular regarding the improvement of physical fitness and functionality.[33] In fact, a beneficial effect of strength training programs is expected on neuromuscular control and partially on morphological adaptations of muscles and tendons[34] as well as on mitigating the risk of injury.[35] Naturally, the strength gains and neuromuscular adaptations (e.g., neuromuscular activity during maximal stretch-shortening cycle, increased muscle fiber size), can be also translated for power-related movements such as the CMJ.[36] Thus, we can sustain that strength-training is effective for improving CMJ height in youth male soccer players as in other similar studies.[37] Additionally, is important to highlight that CMJ performance is strongly related to sprinting, COD which emphasizes the importance of improving CMJ to support other key physical qualities for soccer players.[38]

In our study, a significant improvement in body composition was also observed, in particular, gains in lean mass while body fat decreased in the experimental group. This finding is in line with a study conducted in youth soccer player which presented significant improvements in body composition (namely increase in fat free mass) after strength training combined with regular soccer training sessions.[39] The results are also in line with studies conducted in adult male soccer players which confirm benefits of strength-based training on body composition.[40,41]

Gaining muscle mass (after a strength-based stimulus) can be important to enhance force production, while contributing to mitigating post-match muscular damage.[42] Interestingly, the players from the strength-training group improved not only lean mass (and potentially muscle mass, since body mass also significantly increased) but also decreased fat mass, which helps to contribute to a better athletic performance in youth soccer players.[43,44] Possibly, increases in lean tissue mass and daily metabolic rates (followed by a great energy expenditure considering the combination with regular training session) can contribute to body fat reduction.[45] Moreover, the contribution of strength-based training is also well established for reducing body fat percentage, body fat mass and visceral fat, as recently emphasized by a meta-analysis.[46] Instead, a decrease in body mass could potentially result in an increase in jump height for soccer players based on the impulse momentum relationship, but it's important to consider the specific demand of soccer and the potential trade-off of decreasing body mass.[1]

This study has some limitations. The nutritional dietary and supplementation intake was not controlled over the period, neither were the remaining in-field soccer training sessions monitored. Future research should consider the interaction between diet and the rest of the training sessions with the implementation of strength training, aiming to identify if the improvements occurred due to strength training or despite strength training. Although there are limitations, this study reveals the effectiveness of the current strength-training program for improving body composition (gaining body mass and lean mass, while decreasing body fat) and power-related performance in the CMJ which did not occur in the control group. This confirms that implementation of strength endurance and strength speed training twice a week can be highly recommended for potentially improving the performance of youth soccer players.

Conclusions

The 16-week intervention program carried out with the protocol and method created by Turner and Steward,[26] has meant an improvement in the EG both at the level of body composition and in vertical jump performance, measured with the CMJ test. The results of this study showed that 16-week intervention program resulted in an improvement in the EG both at the level of body composition and in CMJ performance U19 semi-professional male soccer players. Physical trainers and coaches can use strength training to improve their players' overall physical fitness. However, to develop both strength capacity and control during training, soccer players should work with qualified trainers or coaches who can provide feedback and guidance on proper form and technique. In addition, it is important to take this strength capacity into account in training, due to the importance outlined in the sport of soccer both for its transfer to both linear and COD sprints and specific strength skills.

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Contributorship statement

Francisco Tomás González-Fernández: Conceptualization, Formal analysis, Investigation, Writing – Original Draft, Supervision. Lorena Rodríguez García: Investigation, Writing – Original Draft. Alfonso Castillo-Rodríguez: Formal analysis, Writing – Review & Editing. Filipe Manuel Clemente. Weston: Conceptualization, Writing – Original Draft, Supervision.

Declaration of conflicting interests

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