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Resistance and plyometric training for optimal performance in youth soccer players

Entrenamiento de fuerza y pliometría para un rendimiento óptimo en futbolistas juveniles

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Abstract

In youth soccer, systematic resistance training can significantly improve performance. Often, this type of training is carried out during the preparatory season and is interrupted or diminishes its emphasis during the competitive season. The objective of this study was to assess the effectiveness of three consecutive mesocycles of combined resistance training (weightlifting and plyometrics in the first two, plyometrics and changes of direction in the third) to achieve continuous improvements in sprinting, vertical jumps, and changes of direction in male youth soccer players. Eighteen soccer players, with an age of 14.1 ± 0.3 years and no previous experience in structured resistance training, were the subjects of the study. Before and after each mesocycle, athletes were tested in countermovement jump (CMJ), 5m sprint, 10m sprint, 15m sprint, 20m sprint, and change of direction (505 test). Additionally, performance was assessed in specific exercises used in each mesocycle, including squats, Bulgarian squats, unilateral and bilateral hip thrusts, and unilateral and bilateral horizontal jumps (single and multiple). Performance improvements were observed in all analyzed variables across the three mesocycles ($p \leq 0.05$), except for CMJ ($p > 0.05$) in the last mesocycle. Considering that these improvements were attained with relatively low loads compared to those reported in similar interventions with this population, it is inferred that this strategy holds the potential to yield sustained performance enhancements throughout the entire year of training for young soccer players lacking prior experience in resistance training.

Keywords: Youth soccer, resistance training, pliometry, CMJ, change of direction.

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Resumen

En el fútbol juvenil, el entrenamiento sistemático de fuerza puede mejorar significativamente el rendimiento. Con frecuencia, este tipo de entrenamiento se lleva a cabo durante el período preparatorio y se interrumpe o reduce su énfasis en el período competitivo. El objetivo del presente estudio fue evaluar la eficacia de tres mesociclos consecutivos de entrenamiento combinado de fuerza (levantamiento de pesas y pliometría en los dos primeros, pliometría y cambios de dirección en el tercero) para lograr mejoras continuas en el rendimiento de sprint, salto vertical y cambios de dirección en jugadores de fútbol juvenil masculino. Dieciocho jugadores de fútbol, con una edad de 14,1 ± 0,3 años y sin experiencia previa en entrenamiento estructurado de fuerza, fueron los sujetos del estudio. Antes y después de cada mesociclo, se evaluó a los deportistas en salto con contramovimiento (CMJ), sprint de 5m, sprint de 10m, sprint de 15m, sprint de 20m y cambio de dirección (test 505). Además, se evaluó el rendimiento en ejercicios específicos utilizados en cada mesociclo, que incluyeron sentadilla, sentadilla búlgara, empuje de cadera unilateral y bilateral, y saltos horizontales unilaterales y bilaterales (simples y múltiples). Se observaron mejoras en el rendimiento en los tres mesociclos para todas las variables analizadas ($p \leq 0,05$), excepto para el CMJ ($p > 0,05$) en el último mesociclo. Dado que las mejoras de rendimiento se lograron con magnitudes de carga relativamente bajas, en comparación con las reportadas en intervenciones similares en esta población, se infiere que esta estrategia tiene el potencial de generar mejoras sostenidas a lo largo de todo el año de entrenamiento en futbolistas jóvenes sin experiencia previa en entrenamiento de fuerza.

Palabras clave: Fútbol juvenil, entrenamiento de fuerza, pliometría, CMJ, cambio de dirección.

Introduction

Specific physical skills are crucial for attaining high-performance levels in youth soccer (Carnevale et al., 2022). These skills include athletic abilities such as jumping, change of direction (CoD), and straight-line sprinting (Ebben & Blackard, 2001; Rodríguez-Fernández et al., 2019). Improving these particular physical skills increases the probability of success in various soccer maneuvers, including aerial and ground duels, evading defenders, and scoring goals, ultimately influencing the outcome of the competition (Keiner et al., 2021).

Implementing a structured resistance training program for players in this sport becomes essential as it enhances the aforementioned capacities. In support of this, Seitz et al. (2014) conducted a meta-analysis review where they found a transfer between lower limb strength increases and sprint performance (performance improvement: 3.1%, effect size: d = 0.87). Consequently, this form of training holds practical significance for coaches and athletes engaged in sports that involve frequent sprints per match, such as soccer.

Several studies have analyzed the effectiveness of resistance training on players' physical performance in the short or medium term, employing intervention programs lasting from 4 to 16 weeks (Raya-González & Sánchez, 2018; Seitz et al., 2014). However, such durations may not accurately capture the reality of this sport, where teams plan their training across macrocycles encompassing an entire season, aiming to enhance performance in the preseason and sustain it throughout the competitive season. Additionally, when dealing with youth athletes, it is imperative to consider the prospective development of the players. This entails exercising caution to avoid loads and load increments that may be excessive for a developing organism (Peña-González et al., 2019).

The present study sought to assess the effectiveness of three mesocycles of combined resistance training (integrating weight lifting and plyometric exercises) over one competitive year on linear sprint, CoD, and counter-movement vertical jump (CMJ) in elite youth soccer players. It is intended as a follow-up of a previous study by the same authors where it was observed that a 16-week resistance training program combining resistance and plyometric exercises resulted in significant improvements in the vertical jump, horizontal jump, and sprint speed over 30m in the same population (Magallanes, Parodi-Feye et al., 2022).

The outcomes of this study could provide valuable insights for coaches and athletes, particularly in team sports at the youth level. This information could aid in selecting exercises, volumes, intensities, forms of progression, and the linking of training mesocycles that, without requiring large training loads, lead to consistent improvements in performance.

Method

Design

This research used a pre-experimental design with convenience sampling. Pre- and post-intervention evaluations were carried out. The study was approved by the Ethics Committee of the Instituto Universitario Asociación Cristiana de Jóvenes (IUACJ) of Uruguay (Resolution No. 10, 12 November 2021). It was conducted following the ethical principles outlined in the Declaration of Helsinki (Rev.2008).

Participants

The sample comprised 30 youth players from the first division of Uruguayan soccer. Inclusion criteria were the following: i) having medical clearance for sporting activity; ii) attending training regularly at the beginning of the intervention; iii) not exhibiting any previous or current injuries or pathologies that could affect performance during the intervention; and iv) not consuming drugs or substances that could potentially alter sporting performance.

Mass, height, and fat percentage were assessed through anthropometry (SECA 213 portable stadiometer; GA.MA professional scale; Harpenden plicometer; Lufkin W606PM anthropometric tape; Lufkin W606PM anthropometric tape) using the Ross and Kerr (1991) body fractionation method and following the procedures described by the International Society for the Advancement of Kineanthropometry (ISAK) (Sirvent & Alvero, 2017).

Prior to the intervention, participants and their legal guardians received detailed information about the study's objectives and procedures. Those who agreed to take part in the study were required to sign the informed consent forms.

Procedures

The players performed their usual training routine throughout the intervention period, engaging in sessions five times weekly, ranging from 90 to 100 minutes per session. They also participated in official

Sunday competitions during the competitive season.

Additionally, the players carried out three mesocycles of resistance training. The first (14 weeks) began during preseason and ended at the beginning of the competition season; the second (12 weeks) and third (10 weeks) were completed during the competition season. The first two mesocycles consisted of workouts combining resistance exercises (half squats and hip thrust) and horizontal plyometrics, while the last mesocycle consisted of horizontal plyometrics and CoDs. A 3-week transition period without resistance training was implemented between each mesocycle, during which on-court training with tactical objectives and assessments took place.

Assessments

Four assessment instances were implemented. All of them were conducted at least 48h after the players´ last training session or competition to ensure complete recovery. The first assessment took place the week before the initiation of the intervention, and subsequent assessments were carried out during the week following the completion of each training mesocycle. In each assessment, all subjects were evaluated on variables representing athletic performance (CMJ, 5m sprint, 10m sprint, 15m sprint, 20m sprint, and the test 505). Additionally, variables specific to each mesocycle were assessed both before and after the completion of it.

For this purpose, assessments included the bipodal horizontal jump (bip_HJ), unipodal right/left horizontal jump (uni_HJ), unipodal right/left horizontal jump speed in 15m (15m_uni_HJ), bipodal triple horizontal jump (bip_3HJ), unipodal right/left triple horizontal jump (uni_3HJ), as well as uni and bipodal hip thrust, Bulgarian squat, and squat tests.

During the two weeks preceding the initial assessment, participants underwent familiarization sessions for the subsequent tests. These sessions aimed to identify and rectify any potential technical errors in execution, thus mitigating the risk of learning bias in the subsequent assessments. The familiarization sessions were conducted after a standardized warm-up. Monday and Wednesday, the players performed a series of CMJ, bip_HJ, uni_HJ, 20m sprint, and 505 tests. Tuesday and Thursday involved a series of 3SHbip, uni_3HJ, and 15m_Uni_HJ tests. Wednesdays and Saturdays included two sets of bilateral and unilateral hip thrusts, Bulgarian squat and half squat with a hexagonal bar. The weight for these exercises was chosen to be perceived as moderate by the athletes (between 3 and 5 on the modified Borg scale). The training and assessment instances are shown in Table 1.

Table 1.
Representation of training and assessment instances

Pre-intervention	Mesocycle 1	Transition period	Mesocycle 2	Transition period	Mesocycle 3	Post-intervention
1 week	**14 weeks**	**3 weeks**	**12 weeks**	**3 weeks**	**10 weeks**	**1 week**

Assessment: CMJ; Sprint 5, 10, 15, 20m; Test 505; Bip_HJ; Uni_HJ; Hip thrust; Squat and Bulgarian Squat	Combined plyometric and resistance training	Assessment: CMJ; Sprint 5, 10, 15, 20m; Test 505; Bip_HJ; Uni_HJ; Hip thrust; Hip thrust uni; Squat and Bulgarian Squat; Uni_3HJ and Bip_3HJ	Combined plyometric and resistance training	Assessment: CMJ; Sprint 5, 10, 15, 20m; Test 505; Hip thrust uni; Uni_3HJ; Bip_3HJ; 15m_Uni_HJ Bulgarian Squat	Combined plyometric and change of direction training	Assessment: CMJ; Sprint 5, 10, 15, 20m; Test 505; 15m_Uni_HJ

Abbreviations: CMJ = Counter-Movement Jump; Uni_HJ = unipodal horizontal jump, Bip_HJ = bipodal horizontal jump; uni_3HJ = triple unipodal horizontal jump; bip_3HJ = triple bipodal horizontal jump; 15m_uni_HJ = 15 meters unipodal horizontal jump.

Source: self made

The CMJ test was performed according to the protocol described by Bosco (2000). In the horizontal long jump tests (uni_HJ, bip_HJ, uni_3HJ, and bip_3HJ), participants were instructed to position the toe/s of their feet at the level of a 2cm wide tape placed on the floor. For bip_HJ and bip_3HJ, participants were asked to place their feet hip-width apart as a starting position. In all instances, they were instructed to exert maximum effort to achieve the longest possible length with a stable landing.

For the triple jumps, three consecutive jumps were executed, culminating in a bipodal landing on the third jump. An attempt was taken as null if the subject fell backward after landing. The jump's distance, measured from toe to heel projection, was recorded. Each subject made two attempts with a passive rest period of at least 2 min between each one, and the best result was considered valid.

In the 15m_uni_HJ tests, time was recorded using photoelectric cells (PROCELL X2) spaced 15m apart. Subjects started from a unipodal equilibrium position. They were instructed to execute unipodal jumps at the highest possible speed towards a mark located 2m beyond the last photocell. Following a 5-minute passive rest, all participants underwent the 20m linear sprint test and the 505 test. Time was measured with high-speed filming (iPhone X, Apple). The protocol by Romero-Franco et al. (2017) was employed for the 20m linear sprint test, and for the 505 test, the application and protocol by Balsalobre-Fernández et al. (2019) were used. The tests were repeated after a 5-minute passive rest, and the best record from both executions was considered valid.

Additionally, to program the training loads for the resistance exercises, progressive load (PL) tests were conducted on Tuesdays and Thursdays during the weeks of the assessments, always under the same conditions. Bulgarian squats with a straight bar, unilateral hip trust, hip thrust, and squats with a hexagonal bar were tested.

For the hexagonal bar squat test, participants started the exercise while seated on an adjustable bench at a height where their knees were positioned at a 90-degree flexion. For the Bulgarian squat test, subjects started with the right lower limb forward and the left lower limb supported with the tip of the foot on a 30cm bench. In both cases, two progressive loads were applied: 10 and 20kg for the hexagonal bar squat and 30 and 50kg for the Bulgarian squat.

For the bilateral and unilateral hip thrust tests, subjects started with the hip positioned in contact with the floor and bar over the pelvis with the knees at approximately 90°. In the unilateral hip thrust, the left leg was raised with hip and knee flexion at approximately 90°. In both cases, two progressive loads were used: 40 and 60kg for bilateral hip thrust and 30 and 50kg for unilateral hip thrust. From this initial position, subjects were instructed to ascend at the maximum possible speed without lifting their feet or heels off the ground. The speed was measured using a linear encoder (Chronojump, Boscosystem). Three consecutive repetitions were performed with each load, with a passive rest period of at least 2min between sets. The average speed of the propulsive phase corresponding to the best repetition of each load was considered to estimate the load used during the experimental intervention. Additionally, the power (in watts) was calculated using the software of the equipment.

Training mesocycles

The first two mesocycles involved a combination of resistance training with weights and horizontal jumps, whereas the focus in the last mesocycle shifted towards horizontal-specific strength exercises (i.e. CoD) and horizontal jumps.

The resistance training in the first two mesocycles comprised linear regressive programming, including unilateral hip thrust and Bulgarian squat for the initial mesocycle and hexagonal bar squat and hip thrust for the second mesocycle. This form of programming is recommended for individuals new to structured resistance training (Gonzalez-Badillo & Serna, 2002). In both mesocycles, participants were instructed to execute the negative (downward) phase in a controlled manner until the knees reached an angle of approximately 90° (squats) or until the buttocks touched the ground (hip thrust). Bulgarian squats were performed using a 30cm bench, as in the test. In both exercises, athletes were required to return to the starting position as quickly as possible after reaching the end position in each repetition.

Following the recommendation of González-Badillo et al. (2017), the weight of the barbell was individually adjusted so that the subject could perform the exercise at an approximate speed of 1.0m/s (mesocycle 1) and 0.9m/s (mesocycle 2). For the exercises involving additional weights, on the first day of each mesocycle, two sets of two repetitions were executed at the maximum speed, measured with a linear encoder, to determine the weight corresponding to a speed between 0.95 and 1.05m/s (mesocycle 1) or 0.85 and 0.95m/s (mesocycle 2). This weight served as the training load for the subsequent four weeks of the corresponding mesocycle.

Once the load was established, it was determined how many repetitions the subjects could perform while maintaining at least 90% of the maximum speed achieved in that series, according to the methodology described by Sánchez-Medina and González-Badillo (2011). Subsequently, this number of repetitions was utilized during the training sessions. After four weeks, this procedure was repeated, adjusting the weight added to the bar and the number of repetitions per set for each subject. The weekly sets were maintained at one or two per exercise throughout the mesocycle (Table 2). Following the methodology Izquierdo et al. (2006) proposed for this population, the rest periods between sets for resistance exercises were passive and lasted 3 minutes. Following Willardson (2006), the rest periods of plyometric exercises were passive and lasted 90 seconds.

The average duration of the complementary training was 21.2 ± 2.1 minutes for plyometric sessions and 4.6 ± 1.0 minutes for resistance training sessions, resulting in an average of 51.6 ± 3.1 minutes per week across the three training mesocycles. A load-unload microcycle dynamic of 4-1, 4-1, 3-1 and 4-1, 4-1, 1-1 was established. During the unloading week, the volume was halved, featuring only one resistance training session and one plyometrics session. The training program used is detailed in Table 2.

Table 2.
Mesocycle 1 and 2 training program. Stable or regressive programming

Week	Plyometric exercises	Series per week of Plyometrics	Plyometric repetitions (p1 / p 2)	Series per week Bulgarian squat (p1) and squat (p 2)	Series per week uni anb bilateral hip thrust
1	Prog. 1.Box jumps: Bip_HJ, Uni_HJ Prog. 2. Acyclic Bip_HJ y Uni_HJ	4	4/4	2	2
2	Prog. 1. Box jumps: Bip_HJ, Uni_HJ Prog. 2. Acyclic Bip_HJ and Uni_HJ	4	4/5	2	2
3	Prog.1. Box jumps: Bip_HJ, Uni_HJ	4	4/6	2	2

	Prog. 2. Acyclic Bip_HJ, Uni_HJ				
4	Prog. 1.Box jumps: Bip_HJ, Uni_HJ Prog. 2. Bip_3HJ, Uni_3HJ	4	4/3	2	2
5	Box jumps: Bip_HJ, Uni_HJ Prog. 2. Bip_4HJ, Uni_4SHJ	2	4/4	1	1
6	Prog. 1. Acyclic HJ: Bip_HJ, Uni_HJ Prog. 2. Bip_5HJ, Uni_5HJ	4	5/5	2	2
7	Prog. 1. Acyclic HJ: Bip_HJ, Uni_HJ Prog. 2. Bip_5HJ, Uni_5HJ	4	5/5	2	2
8	Prog.1. Acyclic HJ: Bip_HJ, Uni_HJ. Prog. 2. Bip_5HJ, Uni_5HJ	4	5/5	2	2
9	Prog. 1. Acyclic HJ: Bip_HJ, Uni_HJ Prog. 2. Bip_5HJ, Uni_5HJ	4	5/5	2	2
10	Prog. 1. Acyclic HJ: Bip_HJ, Uni_HJ Prog. 2. bip_5HJ, Uni_5HJ	2	5/5	1	1
11	Prog. 1. Acyclic HJ:	4	5/5	2	2

	Bip_HJ, Uni_HJ				
12	Prog. 1. Acyclic HJ: Bip_HJ, Uni_HJ	4	5/5	2	2
13	Prog. 1. Acyclic HJ: Bip_HJ, Uni_HJ	4	5	2	2
14	Prog. 1. Acyclic HJ: Bip_HJ, Uni_HJ	2	5	1	1

Abbreviations: Prog. = Progression; HJ = Horizontal Jumps; Uni_HJ = unipodal horizontal jumps; Bip_HJ = bipodal horizontal jumps; Uni_(x)HJ = x number of unipodal horizontal jumps. Note: For the exercises with weights, the intensity and repetitions were adjusted in weeks four, eight and 12. The number of repetitions was established by controlling the speed of execution; when the speed decreased by 10%, the series was terminated.

Source: self made

The third training mesocycle consisted of unipodal horizontal jumps and CoDs. With a frequency of twice a week and rests of at least 72h between sessions, each workout comprised two repetitions at each station (one for each hemibody) in a circuit. The exercises were performed in the following order: Uni_HJ, CoD 180°, Uni_HJ, zigzag 45°and CoD in T. Throughout the entire mesocycle, two laps of the circuit were completed in each session. In weeks 3 and 6, additional meters were added to the distances covered in each exercise. The horizontal jump distance increases from 8m to 20m, the zigzag 45° distance from 10m to 20m, and the CoD distance from 16m to 30m.

Statistical analysis

Data are presented as mean ± standard deviation (SD). Normality was assessed using the Kolmogorov-Smirnov test. If the data met the assumption of normality, the results of the post vs. pre-intervention test were compared using Student's t-test for paired two-tailed data. If normality was not met, the Wilcoxon test was employed.

The magnitude of the differences between groups was quantified by calculating the standardized difference (effect size, ES) using Cohen's d with a 95% confidence interval (CI). Effect sizes equal to or less than 0.20 were considered as having no effect, values between 0.21 and 0.49 as a small effect, values between 0.50 and 0.79 as a moderate effect, and values equal to or greater than 0.80 as a large effect (Caycho et al., 2016).

The significance level for all statistical calculations was set at $p < 0.05$. The calculations were conducted using the free software JASP (Version 0.16.4; JASP Team, 2022).

Results

Although 30 players were initially selected, 12 were excluded for not completing at least 80% of the scheduled intervention sessions. Consequently, data from 18 players (age = 13.7 ± 0.3; mass = 56.6 ± 9.6; height = 168.4 ± 0.1; % fat = 10.3 ± 1.4) were considered for the analysis. Table 3 presents the results obtained in the assessments before and after each training mesocycle.

Table 3.
Results of pre- and post-training mesocycle assessments

Exercises used for training	**Assessment 1**	**Assessment 2**	**Assessment 3**	**Assessment 4**
Squats 30kg (w)	1241.7 ± 135.6	1261.3 ± 140.1*		
Squats 50kg (w)	1235.2 ± 135.7	1252.1 ± 142.9*		
Hip thrust 40kg (w)	1165.6 ± 179.8	1233.1± 181.2*		
Hip thrust 60kg (w)	1170.8 ± 155.6	1244.5 ± 157.3*		
Bulgarian Squat 10kg (w)		1168.5 ± 270.3	1259.2 ± 275.0*	
Bulgarian Squat 20kg (w)		1089.1 ± 244.2	1228.9 ± 241.1**	
Hip thrust uni 30kg (w)		815.9 ± 125.8	882.0 ± 125.1*	
Hip thrust uni 50kg (w)		819.6 ± 108.9	880.3 ± 114.1*	
HJ_left (cm)	178.8 ± 14.8	197.1 ± 13.7*		
HJ_right (cm)	178.3 ± 18.0	194.5 ± 13.3*		
Bip_HJ (cm)	199.8 ± 14.3	215.6 ± 16.3*		
3HJ_ left (cm)		632.6 ± 34.0	652.0 ± 26.7*	
3HJ_right (cm)		641.6 ± 41.6	656.6 ± 28.5*	
bip_3HJ (cm)		670.4 ± 46.1	693.0 ± 38.5	
15m_HJ_left (cm)			3.40 ± 0.22	3.39 ± 0.22*
15m_HJ_right (cm)			3.36 ± 0.23	3.35 ± 0.23*

Performance variables	**Assessment 1**	**Assessment 2**	**Assessment 3**	**Assessment 4**
CMJ (cm)	27.39 ± 3.4	29.16 ± 3.62*	32.58 ± 4.14*	33.01 ± 4.15
Sprint 5m (s)	1.31 ± 0.06	1.235 ± 0.047*	1.15 ± 0.07*	1.11 ± 0.08*
Sprint 10m (s)	2.05 ± 0.07	1.974 ± 0.068*	1,89 ± 0.09*	1.84 ± 0.10*
Sprint 15m (s)	2.73 ± 0.09	2.650 ± 0.084*	2.57 ± 0.11*	2.53 ± 0.10*
Sprint 20m (s)	3.38 ± 0.11	3,278 ± 0.104*	3.28 ± 0.10*	3.16 ± 0.11*
Test 505 (s)	2.47 ± 0.09	2.392 ± 0.105*	2.340 ± 0.079*	2.31 ± 0.08*

Abbreviations: Pre = pre-intervention results; Post = post-intervention results; uni = unilateral; HJ_left = horizontal jump with left foot; HJ_right = horizontal jump with right foot; Bip_HJ = bipodal horizontal jump; 3HJ_left = triple horizontal jump with left foot; 3HJ_right = triple horizontal jump with right foot; bip_3HJ = triple bipodal horizontal jump. Asterisk (*) indicates a significant difference (p < 0.05) with respect to the previous assessment.

Source: self made

Performance variables (CMJ, sprint 5m, 10m, 15m, 20m and 505 test)

After the first training mesocycle, significant improvements were observed in all analyzed variables (CMJ, p = 0.004, d = 0.73; sprint 5m, p < 0.001, d = 1.26; sprint 10m, p < 0.001, d = 1.01; sprint 15m, p < 0.001, d = 1.02; sprint 20m, p < 0.001, d = 0.98; test 505, p = 0.001, d = 0.97). Significant improvements were also observed when comparing performance after the second mesocycle vs. after the first mesocycle (CMJ, p < 0.001, d = 1.01; sprint 5m, p < 0.001, d = 1.28; sprint 10m, p < 0.001, d = 1.14; sprint 15m, p < 0.001, d = 1.14; sprint 20m, p < 0.001, d = 1.01; 505 test, p = 0.025, d = 0.52). After the third mesocycle, significant improvements in all variables were verified, except for CMJ performance which maintained its level (CMJ, p = 0.11; sprint 5m, p < 0.001, d = 1.12; sprint 10m, p < 0.001, d = 1.07; sprint 15m, p < 0.001, d = 1.06; sprint 20m, p = 0.007, d = 0.67; test 505, p = 0.025, d = 0.52).

Performance in the training exercises of the first mesocycle (unilateral hip thrust, Bulgarian squat, Uni_HJ, and Bip_HJ)

After the first mesocycle, performance improved significantly in all analyzed variables (unilateral hip thrust 30kg, p < 0.001, d = 2.18; unilateral hip thrust 50kg, p < 0. 001, d = 2.04; Bulgarian squat 10kg, p < 0.001, d= 1.26; Bulgarian squat 10kg, p < 0.001, d = 2.13; HJ_right, p < 0.001, d = 1.19; HJ_left, p < 0.001, d = 1.28; Bip_HJ, p < 0.001, d = 1.47).

Performance in the training exercises of the second mesocycle (Hip thrust, squat, triple SHi/d, and triple Bip_HJ)

After the second training mesocycle, performance improved significantly in all analyzed variables (hip thrust 40kg, p < 0.001, d = 185; hip thrust 60kg, p < 0. 001, d = 1.81; squat 30kg, p = 0.022, d = 0.72;

squat 50kg, $p = 0.014$, $d = 0.77$; 3HJ_right, $p = 0.026$, $d = 0.56$; 3HJ_left, $p < 0.001$, $d = 1.10$; bip_3HJ, $p < 0.001$, $d = 0.76$).

Performance in the training exercises of the third mesocycle (15m_Uni_HJ)

After the third training mesocycle, performance improved significantly in both tests (15m_HJ_right, $p < 0.001$, $d = 0.81$; 15m_HJ_left, $p = 0.002$, $d = 0.81$).

Discussion

In the present study, a complementary resistance training program combining resistance exercises and horizontal plyometrics in two mesocycles and horizontal plyometrics and CoD in a third mesocycle resulted in significant improvements ($p < 0.05$) in linear sprint and CoD performance in elite youth soccer players.

Previous interventions lasting up to 8 weeks, involving players with similar characteristics to the present study, wherein only soccer-specific training was implemented (without complementary resistance training), did not yield improvements in sprint speed or jumping power (Hammami et al., 2019; Rodriguez-Rossell et al., 2017).

On the other hand, it was observed that relying solely on plyometric exercises for strength development in this population is not sufficient to achieve significant improvements in sprint capacity (Herrero et al., 2006). Additionally, within the same population, a 12-week regimen of isolated resistance training did not lead to improvements in maximal speed in CMJ (although it did in 20m sprint speed) (Magallanes, Magallanes et al., 2022). Similarly, in juvenile male players from another intermittent sport (handball), the isolated use of resistance training with heavy weights for six weeks did not yield improvements in lower limb explosive strength (Gorostiaga et al., 1999).

From a different perspective, a prior study observed that the implementation of combined plyometric and CoD training in youth handball players (U15), similar to the approach used in the third mesocycle of the present study but applied biweekly for eight weeks, led to significant improvements in sprint speed, agility, and horizontal jumps (Hammami et al., 2018), aligning with our findings. It is essential, however, to consider that, unlike the present study, these players had previous experience in resistance training, so the comparison should be interpreted with caution.

Brearley and Bishop (2019) also observed that among the three types of resistance training typically employed (with weights, without weights, and combined), combined resistance training is the most effective in transferring to athletic skills such as sprinting and vertical jumping. Building upon these findings, it seems reasonable to suggest that combining stimuli such as those used in the present study, when applied to youth soccer players, would be the most effective strategy for enhancing physical performance capacities during training and competition seasons.

This study highlights two important aspects: i) the efficiency regarding the intensity of the training stimulus and its impact, and ii) the sustained enhancement observed throughout the entire season in variables that directly reflect the athletes' overall performance. It is noteworthy that the training employed in each mesocycle proved to be not only effective but also efficient, as the performance improvement was achieved with relatively low loads in volume and intensity. This aligns with findings reported by other authors who observed significant improvements in speed and jumping power in youth soccer players after six weeks of combined resistance training using low loads (45 to 60% of 1RM in squats) and low volumes (2 to 3 sets, 4 to 8 repetitions per set) combined with plyometrics, at a frequency of 2 times per week (Franco-Márquez et al., 2015).

When comparing the intervention in our study with similar research conducted on populations of similar age, sport, or prior experience in structured resistance training, a comparable improvement in performance is observed. Notably, the improvements of our study were achieved with significantly lower training volumes.

To illustrate this point, in terms of the duration of the supplementary resistance training, the average time of the three interventions used in the present study was 53.6 ± 3.1min weekly, significantly lower than those used by Hammami et al. (2017) and Rodriguez-Rossell et al. (2017), who averaged 90 and 75min of weekly supplemental training, respectively. Furthermore, other studies conducted with similar populations and interventions to our current work, even when employing considerably higher load magnitudes, showed smaller performance increases (lower ES) for CMJ and sprint speed than those obtained in the present study (Garcia-Pinillos et al., 2014; Gonzalez-Badillo et al., 2015; Hammami et al., 2017; Hammami et al., 2019).

Typically, the training strategy in intermittent team sports is to enhance players' athletic performance in the preseason and then try to maintain it during the competition period (McMaster et al., 2013). In the present study, during mesocycles 2 and 3 (carried out during the competition period), there was not only an absence of decline in the performance of the analyzed capacities but also a significant increase in performance.

The sustained improvement observed throughout the macrocycle may be partly attributed to the potential for strength development in adolescents, especially those with limited prior training experience in this capacity (Behringer et al., 2010). The training strategy for all three mesocycles in the present intervention aimed to apply the minimum stimuli necessary to elicit positive adaptation.

This study had several limitations. The participants' age and relatively limited experience with the tests may have introduced a learning bias. It would have been desirable to determine the maturity stage of the players, as it can impact performance in tests administered at these ages (Malina et al., 2004). Moreover, due to the nature of this research (professional practice), it was only feasible to control a subset of potential interfering variables. Additionally, the present study lacked a control group. This final limitation was addressed in two ways: firstly, by using as a reference the CMJ and sprint speed data reported by other authors for youth soccer players who did not undergo complementary resistance training, and secondly, by making comparisons with studies that utilized samples and treatments similar to those applied in this study.

Conclusions

In young soccer players without prior experience in systematic resistance training, the implementation of three mesocycles lasting 14, 12, and 10 weeks, which combined resistance and plyometric training with low volume and intensity, along with a carefully gradual increase in the loads, proved to be effective and efficient to improve linear displacement speed, CoD, and lower limb power, with sustained improvements throughout each mesocycle.

The findings of this study indicate that, in youth soccer players, a training strategy that aims for continuous performance improvement throughout the entire sporting year, including both the training and competition season, is not only viable but may also be more effective than the conventional approach that predominantly focuses on maintaining athletic form during the competition season.

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