

Effects of combined plyometric and sled training on vertical jump and linear speed performance in young soccer players

Efectos de la combinación de entrenamiento pliométrico y de arrastres sobre el rendimiento en salto vertical y la velocidad lineal en jugadores jóvenes de fútbol

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Abstract. The objective of this study was to evaluate the effects of a combined plyometrics and sled training carried out two days a week for 8 weeks. 60 young male soccer players were distributed in 4 groups (Under U16) [Experimental Group (U16 Exp, n=15) and Control Group (U16 Cont, n=15); and (Under19) [U19 Exp, (n=15) and U19 Cont, (n=15)]. The jump with countermovement (CMJ) was evaluated with Chronojump-Boscosystem® and the time in seconds (sec) in the 10, 20, and 40 m split with FitLight Trainer®. Was calculated a level of significance of $p > 0.05$, the effect size (ES) and % change. Both experimental groups improved from pre-to post-test in CMJ [U16Exp ($p < 0.02$) and U19Exp ($p < 0.01$)] and the 10, 20, and 40 m splits [U16Exp ($p < 0.02$, $p < 0.03$, and $p < 0.01$, respectively) and U19Exp ($p < 0.02$, $p < 0.02$, and $p < 0.01$, respectively)]. Therefore, the combination of football and plyometric and resisted methods can be used for a general development of the neuromuscular capacities of young soccer players.

Keywords: young players; explosive strength; countermovement jump; Chronojump; FitLight Trainer.

Resumen. El objetivo fue evaluar los efectos de un entrenamiento combinado de pliometría y arrastres realizado 2 días en semana durante 8 semanas. 60 jugadores jóvenes de fútbol fueron distribuidos en 4 grupos (Cadete (CAD) [Grupo Experimental (CADExp n= 15) y Grupo Control (CADCont n= 15)] y Juvenil (JUV) [JUVExp n= 15 y JUVCont n= 15]). Se evaluó el salto con contramovimiento (CMJ) con Chronojump-Boscosystem® y el tiempo en segundos (seg) en los tramos de 10, 20, y 40 m con FitLight Trainer®. Se calculó en nivel de significación $p > 0.05$, tamaño del efecto (TE) y % de cambio. Los grupos experimentales mejoraron del pre al post-test en CMJ [CADExp ($p < 0.02$) y JUVExp ($p < 0.01$)] y los tramos de 10, 20, y 40 m [CADExp ($p < 0.02$, $p < 0.03$, $p < 0.01$, respectivamente) y JUVExp ($p < 0.02$, $p < 0.02$, $p < 0.01$, respectivamente)]. Por tanto, la combinación de fútbol y métodos pliométricos y resistidos puede utilizarse para un desarrollo general de las capacidades neuromusculares de los futbolistas jóvenes.

Palabras clave: jugadores jóvenes; fuerza explosiva; salto con contramovimiento; chronojump; FitLight Trainer.

Introduction

Soccer requires a lot of high intensity actions that include sprinting with periods of acceleration and deceleration, jumps, sprints, and changes of direction (Benítez-Jiménez, Falces-Prieto & García-Ramos, 2020; Gómez-Álvarez et al., 2020). Concerning to soccer, it also need to be mentioned that it is an acyclic and intermittent sport in which performance is highly influenced by actions realized at a high intensity (González-Millán et al., 2014; Sáez de Villarreal, Suárez-Arrones, Requena, Haff, & Ferrete, 2015). The sports are characterized by high intensity actions are explosive

and essential in young and senior soccer players (Bougezzi et al., 2019; Meylan & Malatesta, 2009). Nevertheless, the intermittent nature of the game implies mixed metabolic involvement (Bangsbo, Mohr, & Krstrup, 2006), and the decisive actions depend on the anaerobic energy systems (Raya-González & Sánchez-Sánchez, 2018). The intervention of anaerobic systems in soccer player training must materialize through strength training (Hoff & Helgerud, 2004; Raya-González & Sánchez-Sánchez, 2018), since there is a great relation between sprint, vertical jump and change of direction with the levels of strength, power and ratio of strength production (Swinton, Lloyd, Keogh, Agouris, & Stewart, 2014). Moreover, a review of current literature demonstrates that soccer players require high muscle strength levels, especially in lower body (Falces-

Prieto et al., 2020; Suchomel, Nimphius, & Stone, 2016), to carry out the previously mentioned high intensity actions. In fact, it is well known that strength and speed are very important physical manifestations for soccer players (Gissis et al., 2006; Reilly, Bangsbo, & Franks, 2000), for this, they are considered predictors of success (González-Millán et al., 2014; Kaplan, Erkmen, & Taskin, 2009; Mujika, Santisteban, & Castagna, 2009). Finally, and accordingly with the literature, we can suggest that two of the procedures to improve both qualities properly are plyometric training and resisted methods (García-Ramos & Peña-López, 2016).

Traditionally, plyometrics training was damaging for young population, since it increased injury risk and growth delay (Lloyd et al., 2014). However, recent studies have shown that plyometric training could be beneficial effects for young soccer players when the appropriate training rules for their age are followed (Bedoya, Miltenberger, & López, 2015; Falces-Prieto et al., 2018; Fonseca et al., 2020). Actually, plyometrics training has been recommended to improve vertical and horizontal jump ability (Asadi, Ramírez-Campillo, Arazi, Sáez de Villarreal, 2018; Zisis, 2013). In addition, this training improves acceleration and sprint ability (Bougezzi et al., 2019) and enhances muscle-tendon ability to produce maximum strength levels in short periods of time (<250 ms) (Bougezzi et al., 2019; Sáez de Villarreal, Requena, & Cronin, 2012). The improvement of vertical jump is a common objective, both for researchers and for coaches and strength and conditioning coaches of different sport disciplines (Martínez-Rodríguez, Mira-Alcaraz, Cuestas-Calero, Pérez-Turpín, & Alcaraz, 2017). The possibility of jumping more than the opponent could be a reason of success in athletic competitions, as well as an advantage over an opponent in team sports (Sánchez-Sixto & Floría-Martín, 2017).

On the other hand, resisted methods are those training ways in which the specific technique of sprint is imitated adding an overload on the athlete (Rumpf et al., 2015). Resisted sprint training consists of executing sprinting exercises with additional overload, which is supposed to more effectively transfer to sport performance (Gil et al., 2018). Some authors recommend some resisted methods for the improvement of the acceleration phase (distance 0-20 m) and others for the maximum speed phase (distance 20-50 m), on the basis of the principle of specificity of training (Cahill et al., 2019; Cronin & Hansen, 2006). These methods include sled, parachute, vests or belts

ballast, beach sand runs, and uphill runs (Alcaraz, Elvira, & Palao, 2009a). Regarding the use of dragging with sleds and the load to be moved in football players, some authors recommend from 5-7% (Alcaraz, Palao, & Elvira, 2009b) to 69-96% of the body weight (Cross, Brughelli, Samozino, & Morin, 2017). The implementation of this methodology seeks that the muscles used in the sprints work in overload, since it causes a greater neural activation, and a greater recruitment of fast contracting motor units (Faccioni, 1994).

Due to the great number of factors that affect the performance of both the strength (Cronin & Sleivert, 2005), and the sprint (Radford, 1990), and the unawareness regarding the most optimal method of strength and speed training (Cronin & Sleivert, 2005), it is necessary to optimize the knowledge about the athlete's preparation and the training's effect on the performance (Jiménez-Reyes, Cuadrado-Peñañiel, & González-Badillo, 2011). Although numerous researchers on football have proved that both the plyometric training and the dragging, independently, can produce improvement on the vertical jump height and the speed respectively (Alcaraz et al., 2009a; Bougezzi et al., 2019; Sáez de Villarreal, González-Badillo, & Izquierdo, 2008), we doubt about the combination of both as an effective and optimal method for the enhancement of young football players. Therefore, the aim of the present study this research was to examine and evaluate the effects of a combined plyometrics and sled training carried out two days a week during 8 weeks in young football players, on the improvement of the vertical jump and linear speed ability.

Material and Method

Participants

A group of sixty young male soccer players belonging a High-Performance Soccer Academy and competed in federated competition at the regional level, voluntarily participated in the study, which was performed according to the ethical standards established by the Helsinki Declaration of 2017. They were divided according to the category (Under 16 & Under 19) and randomly. The groups were: U16 [Experimental Group (U16 Exp) n= 15: age: 14.17 ± 0.41 years, height: 169.75 ± 2.52 m, weight: 56.90 ± 5.76 Kg; Control Group (U16 Con) n= 15: age: 14.70 ± 0.48 years, height: 167.50 ± 5.23 cm weight: 53.43 ± 6.47 Kg]

and U19 [(U19 Exp) n= 15: age: 17.17 ± 0.98 years, height: 171.62 ± 2.18 cm, weight: 65.32 ± 3.76 Kg; (U19 Con) n= 15: age: 17.00 ± 0.58 years, height: 172.64 ± 6.80 cm, weight: 63.21 ± 7.06 Kg]. All participants had been playing soccer for more than five years and at the time of the present research they were recruited in High-Performance Soccer Academy. In fact, all participants were recruited via flyers and they reported normal or corrected to normal vision, had no history of neurological or physical disorders, and gave informed consent prior to the start of the experiment. The players practiced 5 times per week, 90 min per session, with an official competition every weekend. All players participated in 16 proposed sessions (100%). All participants and parents were carefully informed of the experimental procedures and possible risk and benefits associated with participation in the study.

All the participants complied with inclusion and exclusion criteria. Inclusion criteria: (1) being active players of the high-performance academy, (2) not presenting any injury during the last 3 months, (3) having the consent and (4) carrying out at least 80% of the training protocol. Exclusion criteria: (1) not complying with 80% of the training protocol and (2) presenting any ailment or acute disease at the time of the intervention.

Procedure

The intervention was carried out during the months of October and November of the 2019/2020 season. One-hour sessions were scheduled two days a week on non-consecutive days (Tuesday and Thursday), over a period of 8 weeks (see table 1). In addition, to the plyometric and sled training, the experimental group continued with its training program that included 5 technical-tactical sessions per week and a competition match on the weekend. For its part, the control group only carried out the normal dynamics of technical-tactical training and competition matches. The combined training program was performed after a warm-up, as it has been recommended as the best time to perform plyometric training (Bedoya et al., 2015), in addition to ensuring that players were rested and obtained better benefits of the program (Meylan & Malatesta, 2009). Regarding the organization of training, a circuit organization was followed for the benefits of this type of distribution (Orquín-Castrillón, Torres-Luque, & Ponce de León, 2009).

The 10-minute warm-up was based on dynamic movements of both the upper and lower body,

performed in rows and with a displacement of 15 meters, under the direct command of the strength and conditioning coach (Falces-Prieto et al., 2018). As seen in the studies by Falces-Prieto et al. (2020) and Sáez de Villarreal et al. (2015), plyometric exercises consisted of exercises performed at maximum voluntary intensity using the player's body weight or body weight with light resistance. Regarding sled training, the material used was a galvanized sled (RANKING©, Navarra, Spain) with a 54x38 cm platform, total length of 94 cm and weight without load: 4.5 kg and discs of different weights of the DOMYOS© brand (Lille, France) to carry the trailers with the correct load. The load was the weight of the sled itself and 5, 12.5 and 20% of the player's body weight (weight of the sled included), as in the study by Bachero-Mena & González-Badillo (2014).

For their evaluation, the participants visited the laboratory on two separate occasions (before and after the intervention), always at the same time of the day (U16 group at 15:30 and U19 group at 16:30) and evaluated by the same technical specialists. Both for the pre and post-evaluation of the CMJ and the speed, the players first performed a 10-minute warm-up based on: free joint and muscle mobility (3 min), skipping (2x30 seconds), gluteal heel (2x30 seconds), squats with extended arms (2x10 repetitions), continuous vertical jumps (6 jumps with the CMJ execution technique) and two progressive high-speed runs of 10 m. In the first place, the CMJ was evaluated in the laboratory and immediately afterwards, the speed evaluation was carried out in the field. The evaluation system was carried with a contact platform Chronojump-Boscosystem® (Barcelona, Spain) (De Blas, Padullés, López-Del Amo, & Guerra-Balic, 2012; Pueo, Jiménez-Olmedo, Lipińska, Buceko, & Penichet-Tomás, 2018). 3 CMJ jumps were performed, with a recovery time of 20 seconds between jumps and the average of the three jumps for analysis. The measurement was carried out with Chronopic and recorded with the Chronojump software version 1.4.7.0 (García-Ramos & Peña-López, 2016).

For speed evaluation, 2 attempts were performed with a recovery time of 2 min between repetitions and an average of the two repetitions for subsequent analysis. Times were measured in seconds (sec) at distances of 10, 20 and 40 m, respectively. The evaluation system was carried out through FitLight Trainer® sensors (Ontario, Canada). This system is used to calculate agility, reaction time, speed and coordination in football (Rauter et al., 2018; Reigal-Garrido et al., 2019). For the

evaluation, 4 Led sensors were placed on a bar 1 m high and in a straight line at distances 10, 20 and 40 m. At the light signal, the player sprinted in a straight line down an 80-cm lane from the sensor. The recorded time for each of the players was stored in a portable tablet with an Android system and its subsequent analysis in the Microsoft Windows® Excel program (Redmond, Washington, USA).

Table 1. Combined plyometrics and sled training protocol.

Period	Exercises
Week 1 and 2	3 x 10 Jumps fence (20 cm)
	3 x 10 Bipodal landings from box (30 cm)
	3 x 20 Jumps forward and back
	3 x 10 Power Skips
	2 x 10 m sled (weight of the sled)
Week 3 and 4	2 x 15 m sled (weight of the sled)
	3 x 15 m Unipodal horizontal jumps (right-left leg)
	3 x 10 Drop Jump (30 cm)
	3 x 10 Lateral Hops fence 10 cm
	3 x 10 Jumps to box (30 cm)
Week 5 and 6	2 x 15 m sled (5% body weight)
	2 x 20 m sled (5% body weight)
	3 x 10 Jumping Lunges
	3 x 8 Frontal Jumps fence (30 cm)
	3 x 10 Drop Jump (30 cm) + sprint 10 m
Week 7 and 8	2 x 20 m sled (12.5% body weight)
	2 x 30 m sled (12.5% body weight)
	3 x 10 Unipodal Landings from box (30 cm)
	3 x 20 m bipodal frontal vertical jump frequency
	3 x 20 m frequency vertical jumps backward bipodal
	3 x 15 unipodal vertical jumps (right-left leg)
	2 x 30 m sled (20% body weight)
	2 x 40 m sled (20% body weight)

Note: S x R (series x repetitions); cm (centimeters); % (percentage).

Statistical Analyses

Descriptive statistics are represented as mean and standard deviation (SD). Test of normal distribution (Shapiro Wilk test) was conducted on all data before analysis. The sample was normal and additionally parametric T-Student test of related samples was performed. The statistical analysis was completed with the effect size (ES) using the Cohen's d (1988) to evaluate the magnitude of the differences and the % change from pre to post-test is presented. The criteria for understanding the effect size was: trivial = 0.00-0.19; small = 0.20-0.59; moderate = 0.60-1.19; large = 1.20-1.9; very large = 2.0-4.0; and almost perfect >4, (Hopkins, 2002). The level of significance was $p < 0.05$. Data analysis was performed using JASP® statistical program (version 0.11.1, Amsterdam, The Netherlands).

Results

The changes in the variable height (cm) of the CMJ and the time (sec) in the distances of 10, 20 and 40 m are shown in Table 2.

CMJ performance

Significant performance improvements occurred

both in U16 Exp ($p < 0.02$; ES: 0.41; %: 2.09), and in U19 Exp ($p < 0.01$; ES: 0.56; %: 5.11), respectively, between the pre-and post-tests.

Linear speed

The results obtained regarding the time variable (sec) in the linear speed test of 10, 20 and 40 m, only the U16 Exp groups (10 m: $p < 0.02$; ES: 0.46; %: 2.98; 20 m: $p < 0.03$; ES: 0.51; %: 2.11; 40 m: $p < 0.01$; ES: 0.55; %: 4.03) and U19 Exp (10 m: $p < 0.02$; ES: 0.49; %: 5.64; 20 m: $p < 0.02$; ES: 0.48; %: 4.05; 40 m: $p < 0.01$; ES: 0.47; %: 2.11), show a significant decrease between pre and post-tests, in the times of each split.

Table 2. Comparison of the variable height (cm) in CMJ and time (sec) in the linear speed test (10-20-40 m) of the pre-test and post-test (mean \pm SD) in U16 and U19 category.

Test		U16		U19	
		U16 Exp	U16 Con	U19 Exp	U19 Con
CMJ (cm)	Pre	33.90 \pm 4.17	32.97 \pm 4.75	36.76 \pm 3.97	36.87 \pm 4.32
	Post	34.61 \pm 4.54	33.09 \pm 4.51	38.64 \pm 4.09	37.02 \pm 4.40
	p	0.02*	0.28	0.01*	0.19
	ES	0.41	0.34	0.56	0.44
10 m (sec)	Pre	2.01 \pm 0.11	2.04 \pm 0.13	1.95 \pm 0.15	1.98 \pm 0.15
	Post	1.95 \pm 0.08	2.03 \pm 0.13	1.84 \pm 0.10	1.95 \pm 0.09
	p	0.02*	0.12	0.02*	0.19
	ES	0.46	0.31	0.49	0.34
20 m (sec)	Pre	3.32 \pm 0.15	3.33 \pm 0.21	3.21 \pm 0.12	3.20 \pm 0.20
	Post	3.25 \pm 0.18	3.32 \pm 0.20	3.08 \pm 0.17	3.21 \pm 0.19
	p	0.03*	0.26	0.02*	0.25
	ES	0.51	0.12	0.48	0.11
40 m (sec)	Pre	5.96 \pm 0.40	5.99 \pm 0.39	5.69 \pm 0.34	5.70 \pm 0.38
	Post	5.72 \pm 0.31	5.91 \pm 0.27	5.57 \pm 0.32	5.69 \pm 0.42
	p	0.01*	0.11	0.01*	0.10
	ES	0.55	0.34	0.47	0.31

Note: U16Exp (experimental U16group); U16Con (control U16 group); U19Exp (experimental U19 group); U19Con (control U19 group); SD (standard deviation); m (meters); cm (centimeters); sec (seconds); Level of significance ($p = 0.05$ *); ES (effect size); % (% of change).

Discussion

The main purpose of this study was to evaluate the effects of a combined plyometric and sled training for 8-weeks and carried out two days a week in young soccer players for improving the ability of vertical jump and linear speed. This study highlights a new approach that combine plyometric and sled training methods in young soccer players.

Through the present study, it is concluded that our protocol produces improvements in variable height in CMJ and sprint time in the speed sections of 10, 20 and 40 m respectively in both categories (see table 2 for more information). On the one hand, the results obtained are in line with the research of Alcaraz et al. (2009b) and Sáez de Villarreal et al. (2008), which have shown that plyometric and sled training produce improvements in jump height and speed respectively ($p < 0.001$). We can suggest that the duration of our study has been optimal to produce neuromuscular adaptations

in both categories, since they have followed the optimal guidelines such as a minimum duration of 8 weeks, multiple series and 1-2 days per week (Bouguezzi et al., 2020; Lloyd et al., 2014; Peña, Heredia, Lloret, Martín. & Da Silva-Grigoletto, 2016).

A deep review of the literature reveals that a cross of plyometric and sled training in the same intervention process in young soccer players is justified by the study by Fatouros et al. (2000), who agree that in order to optimize the results of a plyometric training, it must be combined with other training methods. We can indicate that after combining plyometric and sled training, we have found improvements in CMJ in U16 Exp ($p < 0.02$; 2.09 %) and U19 Exp ($p < 0.01$; 5.11%) and sprint time in the distance 0-40 m in U16 Exp ($p < 0.01$; 4.03%) and Exp U19 ($p < 0.01$; 2.11%). Our data is in agreement with Buchheit, Méndez-Villanueva, Delhomel, Brughelli. & Ahmaidi, (2010), who planned a cross training (jumps, coordination and speed stairs; 4-6 series 4-6 exercises; 45 seconds of recovery between series and 3 minutes of recovery between exercises) of 10 weeks, achieving improvements in CMJ (14.68%) and in the sprint time in 30 m (1.96%). On the other hand, a study of Chelly et al. (2010), proposed an 8-week plyometric training program (2 weekly sessions) during the season, finding significant improvements ($p < 0.01$) of 9.75% in maximum speed (m/s) and 10% in acceleration (m/s). Furthermore, they obtained statistically significant improvements in CMJ ($p < 0.01$; 2.5%). Finally, we must highlight the work of De Hoyos et al. (2016) with elite Spanish soccer players ($n = 11$) who carried out an 8-week with a plyometric training program during a season (twice a week), which consisted of the combination of jumping exercises, coordination ladder and sprint. After the completion of the program, the results obtained showed improvements in CMJ (7.2%), in the sprint time of 30-50 m (s) of 0.3% and in the maximum speed of 0-50 m (s) of 1.5%.

The literature found until the present recommends that for a resisted training to be effective, it should not produce losses greater than 10% (Alcaraz, 2010; Gil et al., 2018). The proposed loads on sled training have generated a significant performance increase of 4.03% in U16 Exp and 2.11% in U19 Exp in the 0-40 m distances. Therefore, we can indicate that our protocol offered overload control by allowing no more than 10% reductions in sprinting speed. The relationship between load and the improvement of time in the 10, 20 and 40 m sections in U16 Exp (ES: 0.46, 0.51 and 0.55) and U19 Exp (ES: 0.49, 0.48 and 0.47), are close to the

results obtained by the studies mentioned. In this sense, these authors shown improvements in performance of 5 and 20 m (ES: 0.60) in amateur soccer players (26.3 ± 4.0 years), after performing sled training with 80% of body weight (10 x 20 m sprints), carried out two days a week before training, for 8-weeks. Thus, our results of CMJ and linear speed results using sled training coincided with the study by Spinks, Murphy, Spinks, & Lockie, (2007), which showed that with a resisted training carried out 2 days a week over 8-weeks, there were improvements in CMJ ($p < 0.001$) time in 0-5 m ($p < 0.001$), distances 5-10 m ($p < 0.05$) and distances 10-15 ($p < 0.05$) respectively in soccer players ($n = 8$). Furthermore, the results obtained in our study differ from those obtained by García-Ramos & Peña-López (2016), who demonstrated that after the combination of a plyometric training and a resisted training through the dragging of sleds with loads of between 10 and 20% of body weight, performed two days a week for 8-weeks, did not show significant improvements in CMJ ($p < 0.28$) and sprint time in 10 and 30 m ($p < 0.33$; $p < 0.14$), respectively, in amateur soccer players. This study had some limitations, including that do not provide a comparison between the combined plyometric and sled training with both training methods in isolation, a comparison of the results of this study (combined plyometric and sled training). Future studies should extend the data available in the scientific literature of the effects of isolated plyometric and sled training should be made to improve the knowledge on the topic explaining why it is better or not to combine both methods, especially considering the importance of this type of training on soccer.

Finally, we must bear in mind that training stimuli influence differently according to category and age, and may significantly affect jump performance and speed in young football players (Quagliarella et al., 2011), either by level of biological development, maturation of their musculoskeletal structures or maladjustment to training stimuli, although they improve as the age of the subjects increases (Benítez-Sillero, Da Silva-Grigoletto, Muñoz-Herrera, Morente-Montero, & Guillén-Castillo, 2015). In this sense, plyometric method significantly enhances speed and speed and velocity-force in male soccer players in the short term (Meylan & Malatesta, 2009). To emphasize this point, other study of Thomas et al., 2001, shown that short plyometric training demonstrates significant improvement in vertical jump and agility time in young men. These data are endorsed in our study, when it can be observed that, in the

performance variables evaluated, performance has been higher in the U19 category compared to the U16 category.

Conclusion

In conclusion, the present study demonstrated, that implementing two strength training methods (plyometric and sled training), carried out two days a week on non-consecutive days and for 8 weeks, in addition to normal soccer training and can be recommended as an optimal form of physical conditioning to improve vertical jumping and sprints in young football players. Moreover, it must be considered which is the most appropriate plyometric and sled training for each age range, and for this, we can rely on movement patterns, technique, volume, frequency, intensity and required energy systems. However, coaches and / or strength and conditioning coaches due dominates the load control for applicate on soccer training Thus, should take into account and evaluate each player for adapted the training individually. It should therefore like to highlight the results obtained in this study, when prescribing an appropriate training based on age and sport category.

References

- Alcaraz, P. (2010). Sprint training with resisted sprint training methods. *Cultura, Ciencia y Deporte*, 5(15), 19-26.
- Alcaraz, P., Elvira, J. L., & Palao, J. M. (2009a). Characteristics and effects of resisted sprint training method. *Cultura, Ciencia y Deporte*, 4(12), 179-187.
- Alcaraz, P., Palao, J. M., & Elvira, J. L. (2009b). Determining the optimal load for resisted sprint training with sled towing. *Journal of Strength & Conditioning Research*, 23(2), 480-485.
- Asadi, A., Ramirez-Campillo, R., Arazi, H., & Sáez de Villarreal, E. (2018). The effects of maturation on jumping ability and sprint adaptations to plyometric training in youth soccer players. *Journal of Sports Sciences*, 36(21), 2405-2411.
- Bachero-Mena, B., & González-Badillo, J. J. (2014). Effects of resisted sprint training on acceleration with three different loads accounting for 5, 12.5, and 20% of body mass. *Journal of Strength & Conditioning Research*, 28(10), 2954-2960.
- Bangsbo, J., Mohr, M., & Krstrup, P. (2006). Physical and metabolic demands of training and match-play in the elite football player. *Journal of Sports Sciences*, 24(07), 665-674.
- Bedoya, A. A., Miltenberger, M. R., & López, R. M. (2015). Plyometric training effects on athletic performance in youth soccer athletes: a systematic review. *Journal of Strength & Conditioning Research*, 29(8), 2351-2360.
- Benítez-Jiménez, A., Falces-Prieto, M., & García-Ramos, A. (2020). Jump performance after different friendly matches played on consecutive days. *Revista Internacional de Medicina y Ciencias de la Actividad Física y del Deporte*, 20(77), 185-196.
- Benítez Sillero, J. D., Silva-Grigoletto, D., Muñoz-Herrera, E., Morente-Montero, A., & Guillén-del Castillo, M. (2015). Capacidades físicas en jugadores de fútbol formativo de un club profesional. *Revista internacional de Medicina y Ciencias de la Actividad Física del Deporte*, 15(58), 289-307.
- Bouguezzi, R., Chaabene, H., Negra, Y., Moran, J., Sammoud, S., Ramirez-Campillo, R., & Hachana, Y. (2019). Effects of jump exercises with and without stretch-shortening cycle actions on components of physical fitness in prepubertal male soccer players. *Sport Sciences for Health*, 16, 297-304.
- Bouguezzi, R., Chaabene, H., Negra, Y., Ramírez-Campillo, R., Jlalía, Z., Mkaouer, B., & Hachana, Y. (2020). Effects of Different Plyometric Training Frequencies on Measures of Athletic Performance in Prepuberal Male Soccer Players. *Journal of Strength & Conditioning Research*, 34(6), 1609-1617.
- Buchheit, M., Méndez-Villanueva, A., Delhomel, G., Brughelli, M., & Ahmaidi, S. (2010). Improving repeated sprint ability in young elite soccer players: repeated shuttle sprints vs. explosive strength training. *Journal of Strength & Conditioning Research*, 24(10), 2715-2722.
- Cahill, M.J., Cronin, J.B., Oliver, J.L., Clark, K.P., Lloyd, R.S., & Cross, M.R. (2019). Sled pushing and pulling to enhance speed capability. *Strength & Conditioning Journal*, 41(4), 94-104.
- Chelly, M.S., Ghenem, M.A., Abid, K., Hermassi, S., Tabka, Z., & Shephard, R.J. (2010). Effects of in-season short-term plyometric training program on leg power, jump-and sprint performance of soccer players. *Journal of Strength & Conditioning Research*, 24(10), 2670-2676.
- Cohen, J. (1988). Statistical power analysis for the behavioral sciences (2nd ed). *Psychology Press* (New York, USA).
- Cronin, J., & Hansen, K. (2006). Resisted Sprint Training for the Acceleration Phase of Sprinting. *Strength and*

- Conditioning Journal*, 28(4), 42-51.
- Cronin, J., & Sleivert, G. (2005). Challenges in understanding the influence of maximal power training on improving athletic performance. *Sports Medicine*, 35(3), 213-234.
- Cross, M.R., Brughelli, M., Samozino, P., & Morin, J.B. (2017). Methods of power-force-velocity profiling during sprint running: a narrative review. *Sports Medicine*, 47(7), 1255-1269.
- De Blas, X., Padullés, J.M., López-Del Amo, J.L., & Guerra-Balic, M. (2012). Creation and Validation of Chronojump-Boscosystem: A Free Tool to Measure Vertical Jumps. *RICYDE. Revista Internacional de Ciencias del Deporte*, 8(30), 334-356.
- De Hoyo, M., Gonzalo-Skok, O., Sañudo, B., Carrascal, C., Plaza-Armas, J.R., Camacho-Candil, F., & Otero-Esquina, C. (2016). Comparative effects of in-season full-back squat, resisted sprint training, and plyometric training on explosive performance in U-19 elite soccer players. *Journal of Strength & Conditioning Research*, 30(2), 368-377.
- Faccioni, A. (1994). Assisted and resisted methods for speed development: Part 1. *Modern Athlete & Coach*, 32, 3-6.
- Falces-Prieto, M., Floria-Martín, P., Benítez-Jiménez, A., Revilla-Gil, R., Torres-Pacheco, M., Fuster-Omella, A., Rodicio-Palma, J., & Sáez de Villarreal, E. (2018). Reproducibility of a plyometric protocol in young soccer players. *Revista de Preparación Física en Fútbol*, 28, 11-20.
- Falces-Prieto, M., González-Fernández, F.T., Baena-Morales, S., Benítez-Jiménez, A., Martín-Barrero, A., Conde-Fernández, L., Suárez-Arrones, L., & Sáez de Villarreal, E. (2020). Effects of a strength training program with self-loading on countermovement jump performance and body composition in young soccer players. *Journal of Sport and Health Research*, 12(1), 112-125.
- Fatouros, I.G., Jamurtas, A.Z., Leontsini, D., Taxildaris, K., Aggelousis, N., Kostopoulos, N., & Buckenmeyer, P. (2000). Evaluation of plyometric exercise training, weight training, and their combination on vertical jumping performance and leg strength. *Journal of Strength & Conditioning Research*, 14(4), 470-476.
- Fonseca, R., Castro, J., Santos, A., Lopes, G., Nunes, R., & Vale, R. (2020). Efectos del entrenamiento pliométrico sobre el empuje vertical en jugadores de fútbol en el grupo de edad de 15 a 18 años: una revisión sistemática (Effects of plyometric training on vertical jump in soccer players between 15 and 18 years old: a systemat. *Retos* (39), 981-987.
- García-Ramos, F., & Peña-López, J. (2016). Effect of 8 Weeks of Plyometric and Resisted Sled Sprint Training on Vertical Jump and Sprint Performances of Amateur Football Players. *Revista Kronos*, 15(2), 1-10.
- Gil, S., Barroso, R., Crivoi do Carmo, E., Loturco, I., Kopal, R., Tricoli, V., Ugrinowitsch, C., & Roschel, H. (2018). Effects of resisted sprint training on sprinting ability and change of direction speed in professional soccer players. *Journal of Sports Sciences*, 36(17), 1923-1929.
- Gissis, I., Papadopoulos, C., Kalapotharakos, V.I., Sotiropoulos, A., Komsis, G., & Manolopoulos, E. (2006). Strength and speed characteristics of elite, subelite, and recreational young soccer players. *Research in Sports Medicine*, 14(3), 205-214.
- Gómez-Álvarez, N., Moyano, F., Huichaqueo, E., Veruggio, M., Urrutia, V., Hermosilla, F., & Pavez-Adasme, G. (2020). Effects of The Inclusion of Jump Exercises with and without External Overload in The Warm-Up on Physical Performance Parameters in Young Handball Athletes. *MHSalud*, 17(1), 49-63.
- González-Millán, C., Del Coso-Garrigós, J., Abián-Vicén, J., López-del Campo, R., Gutiérrez, D., & Salinero, J. (2014). Changes in leg muscle strength after a pre-season mesocycle in semiprofessional soccer players. *Retos* (26), 52-55.
- Hoff, J., & Helgerud, J. (2004). Endurance and strength training for soccer players. *Sports Medicine*, 34(3), 165-180.
- Hopkins, W.G. (2002). A scale of magnitudes for effect statistics. A new view of statistics. Recuperado de: www.sportsci.org/resource/stats/effectmag.html
- Jiménez-Reyes, P., Cuadrado-Peñañiel, V., & González-Badillo, J.J. (2011). Application of the Counter Movement Jump Test to Monitor Training Load in Sprint Sessions. *Cultura, Ciencia y Deporte*, 6(17), 105-112.
- Kaplan, T., Erkmén, N., & Taskin, H. (2009). The evaluation of the running speed and agility performance in professional and amateur soccer players. *Journal of Strength & Conditioning Research*, 23(3), 774-778.
- Lloyd, R.S., Faigenbaum, A.D., Stone, M.H., Oliver, J.L., Jeffreys, I., Moody, J.A., & Herrington, L. (2014). Position statement on youth resistance training: the 2014 International Consensus. *British Journal of Sports Medicine*, 48(7), 498-505.
- Martínez-Rodríguez, A., Mira-Alcaraz, J., Cuestas-

- Calero, B. J., Pérez-Turpín, J. A., & Alcaraz, P. E. (2017). Plyometric Training in Female Volleyball Players. Systematic Review. *Retos*, (32), 208-213.
- Meylan, C., & Malatesta, D. (2009). Effects of in-season plyometric training within soccer practice on explosive actions of young players. *Journal of Strength & Conditioning Research*, 23(9), 2605-2613.
- Morin, J.B., Petrakos, G., Jiménez-Reyes, P., Brown, S.R., Samozino, P., & Cross, M.R. (2017). Very-heavy sled training for improving horizontal-force output in soccer players. *International Journal of Sports Physiology and Performance*, 12(6), 840-844.
- Mujika, I., Santisteban, J., & Castagna, C. (2009). In-season effect of short-term sprint and power training programs on elite junior soccer players. *Journal of Strength & Conditioning Research*, 23(9), 2581-2587.
- Orquín-Castrillón, F.J., Torres-Luque, G., & Ponce de León, F. (2009). Effects of a Strength Training Program on Cardio Respiratory Parameters. *Revista Internacional de Medicina y Ciencias de la Actividad Física y del Deporte*, 2(35), 299-311.
- Pueo, B., Jiménez-Olmedo, J.M., Lipińska, P., Buceko, K., & Penichet-Tomás, A. (2018). Concurrent validity and reliability of proprietary and open-source jump mat systems for the assessment of vertical jumps in sport sciences. *Acta of Bioengineering and Biomechanics*, 20(3), 51-57.
- Peña, G., Heredia, J.R., Lloret, C., Martín, M., & Da Silva-Grigoletto, M.E. (2016). Introduction to strength training at early age: A review. *Revista Andaluza de Medicina del Deporte*, 9(1), 41-49.
- Quagliarella, L., Sasanelli, N., Belgiovine, G., Accettura, D., Notarnicola, A., & Moretti, B. (2011). Evaluation of counter movement jump parameters in young male soccer players. *Journal of Applied Biomaterials and Biomechanics*, 9(1), 40-46.
- Radford, P.F. (1990). Sprinting. In: Reilly, T., Secher, N., Snell, P., Williams, C. (Eds.), *Physiology of Sports*. London, (Chapter 3), 71- 99.
- Rauter, S., Èoh, M., Vodièar, J., •van, M., Krizaj, J., Šimenko, J., Szmajda, L., & Krzysztow, M. (2018). Analysis of reactive agility and change of direction speed between soccer players and physical education students. *Human Movement*, 19(2), 68-74.
- Raya-González, J., & Sánchez-Sánchez, J. (2018). Strength Training Methods for Improving Actions in Football. *Apunts: Educació Física i Esports*, 2(132), 72-93.
- Reigal-Garrido, R.E., Barrero, S., Martín, I., Morales-Sánchez, V., Juárez, R., & Hernández-Mendo, A. (2019). Relationships between reaction time, selective attention, physical activity and physical fitness in preteens. *Frontiers in Psychology*, 10, 2278.
- Reilly, T., Bangsbo, J., & Franks, A. (2000). Anthropometric and physiological predispositions for elite soccer. *Journal of Sports Sciences*, 18(9), 669-683.
- Rumpf, M.C., Cronin, J.B., Mohamad, I.N., Mohamad, S., Oliver, J.L., & Hughes, M.G. (2015). The effect of resisted sprint training on maximum sprint kinetics and kinematics in youth. *European Journal of Sport Science*, 15(5), 374-381.
- Sáez de Villarreal, E., González-Badillo, J.J., & Izquierdo, M. (2008). Low and moderate plyometric training frequency produces greater jumping and sprinting gains compared with high frequency. *Journal of Strength & Conditioning Research*, 22(3), 715-725.
- Sáez de Villarreal, E., Requena, B., & Cronin, J.B. (2012). The effects of plyometric training on sprint performance: A meta-analysis. *Journal of Strength & Conditioning Research*, 26(2), 575-584.
- Sáez de Villarreal, E., Suárez-Arrones, L., Requena, B., Haff, G.G., & Ferrete, C. (2015). Effects of plyometric and sprint training on physical and technical skill performance in adolescent soccer players. *Journal of Strength & Conditioning Research*, 29(7), 1894-1903.
- Sánchez-Sixto, A., & Floría-Martín, P. (2017). Efecto del entrenamiento combinado de fuerza y pliometría en variables biomecánicas del salto vertical en jugadoras de baloncesto. *Retos*, (31), 114-117.
- Spinks, C. D., Murphy, A. J., Spinks, W. L., & Lockie, R. G. (2007). The effects of resisted sprint training on acceleration performance and kinematics in soccer, rugby union, and Australian football players. *Journal of Strength & Conditioning Research*, 21(1), 77-85.
- Suchomel, T. J., Nimphius, S., & Stone, M. H. (2016). The importance of muscular strength in athletic performance. *Sports Medicine*, 46(10), 1419-1449.
- Swinton, P. A., Lloyd, R., Keogh, J. W., Agouris, I., & Stewart, A. D. (2014). Regression models of sprint, vertical jump, and change of direction performance. *Journal of Strength & Conditioning Research*, 28(7), 1839-1848.
- Thomas, K., French, D., & Hayes, P.R. (2009). The effect of two plyometric training techniques on muscular power and agility in youth soccer players. *Journal of Strength & Conditioning Research*, 2(1), 332-335.
- Zisis, P. (2013). The effects of an 8 weeks plyometric training program or an explosive strength training program on the Jump-and-Reach Height of male amateur soccer players. *Journal of Physical Education and Sport*, 13(4), 594-600.