Ovidius University Annals, Series Physical Education and Sport / SCIENCE, MOVEMENT AND HEALTH
Vol. XXI, ISSUE 2 Supplement, 2021, Romania
The journal is indexed in: Ebsco, SPORTDiscus, INDEX COPERNICUS JOURNAL MASTER LIST, DOAJ DIRECTORY OF OPEN ACCES JOURNALS, Caby, Gale Cengage Learning, Cabell's Directories

Science, Movement and Health, Vol. XXI, ISSUE 2 Supplement, 2021
September 2021, 21 (2): 567 - 573
Original article

CORRELATIONS BETWEEN BODY COMPOSITION AND STRENGTH IN WOMEN'S SOCCER, HANDBALL AND RUGBY

TROFIN PETRUȚ-FLORIN[1], LEPCIUC GABRIELA[2], MARTINAȘ FLORENTINA-PETRUȚA[3]

Abstract

Objective. The aim of this paper is to analyze the links between body composition, explosive strength and isometric strength in women's football, handball and rugby.

Methods. The research analyzed 44 performance women athletes from the first leagues of Romania, divided into 3 groups: football (N=14, 57.44 ± 9.12 kg, 29.01± 2.16 % muscle mass, 30.09 ± 4.60 % body fat), handball (N= 13, 70.03 ± 8.33 kg, 31.06 ± 1.35 % muscle mass, 28.82 ± 2.34 % body fat) and rugby (N= 17, 58.81 ± 5.18 kg, 31.46 ± 3.45 % muscle mass, 28.48 ± 5.62 % body fat).

Results. To evaluate the explosive strength we applied the Squat Jump (football= 34.62 ± 3.66 cm, handball= 37.69 ± 4.27 cm, rugby= 34.53 ± 6.21 cm), the Countermovement Jump (football= 37.01 ± 4.29 cm, handball= 39.21 ± 4.69 cm, rugby= 35.86 ± 6.22 cm), the Free Jump (football= 42.78 ± 5.31 cm, handball= 44.14 ± 3.90 cm, rugby= 39.78 ± 7.04 cm) and the 4 repeated jumps test (football= 1.89 ± 0.38, handball= 2.03 ± 0.35, rugby= 1.91 ± 0.36). Isometric strength was assessed using the handgrip strength test (football= 60.63 ± 10.84 kg, handball= 70.43 ± 9.37 kg, rugby= 65.08 ± 4.88 kg).

Conclusions. Using Anova One-Way, significant differences were highlighted only in terms of assessing the strength of the palmar flexors (r=0.181, p=0.020). The Pearson correlation showed a direct link between body composition, explosive force and isometric force, for all groups.

Key Words: body composition, strength, performance, team sports.

Introduction

In performance sports, specialists in the field are looking for various methods and means to develop the physical and technical skills of athletes. In team sports, there is an increase in the speed and explosive force of game actions, both during team training and during competitions (Barnes et al., 2014; Bush et al., 2015). In general, these actions with maximum intensity are frequently performed before the decisive situations during the game (Faude et al., 2012).

Handball is classified as a body-contact sport that demands a high level of aerobic and anaerobic fitness. For handball players, successful match performance requires several physical attributes such as speed, power, strength and agility, plus the ability to maintain performance during repeated sprints (Michalsik et al., 2013).

Soccer is considered a contact sport and such impact has had consequences through both a greater skill level and physical demands throughout training and matches (Covic et al., 2016). Female soccer players are exposed to greater training volumes and competition demands than ever before and, therefore, a better understanding of female players' physical performance changes is needed to design appropriate training programs (Pardos-Mainer et al., 2021).

Preparation games in football used to develop muscle strength are not sufficient for adequate adaptive changes. Universal strength training involves the development of maximum dynamic and explosive strength and can effectively take place in the gym. The intensity of this training should be very high, and it is not effective to carry out this exercise with football skills because it may restrict the exercise intensity and therefore the final changes will be smaller in the following developed indicators (Buzek et al., 2002; Pacholek & Zemkova, 2020).

Different intervention programs, such as neuromuscular training, plyometric training, strength training or power training, have been performed to

[1] Faculty of Physical Education and Sport, "Alexandru I.C." Univ. of Iasi, Center of interdisciplinary research in the science of human motricity, Iasi, Rmania,
[2]The State University of Physical Education and Sport Chișinău, Republica Moldova,
[3]Faculty of Physical Education and Sport, "Alexandru Ioan Cuza" University of Iași, Romania,
Corresponding author: trofin.florin@uaic.ro, 0754288343, gabriela_lepciuc@yahoo.com, 0757426943, petruta.martinas@uaic.ro.
Received 16.03.2021 / Accepted 23.05. 2021

improve physical capacities. However, there are discrepancies about which are the best exercises to improve female soccer players' performance due to the lack of studies (Pardos-Mainer, Casajus & Gonzalo-Skok, 2020; Pardos-Mainer, Casajus & Gonzalo-Skok, 2019; Shalfawi et al., 2013; Ramirez-Campillo et al., 2019).

Sports performance is dependent on the methods, means and tasks used in the training process (Loturco et al., 2015), and in this regard numerous studies have been conducted that investigated the impact of training strategies on the physical abilities of athletes (Loturco et al. , 2013a; Loturco et al., 2013b).

Previous studies have shown that during seven consecutive seasons from 2006 to 2013, professional football players in the English Premier League have significantly developed their speed and torque, skills needed to do in the face of intense demands during the match and to achieve professionalism (Barnes et al., 2014; Bush et al., 2015; Ford et al., 2011; Williams, 2016).

In the case of athletes who need a higher speed to be able to cope with the demands during the game, such as rugby players in front of an opposing attack, it is recommended to use loads in training, in making knee bends (Nibali et al., 2013) . Regarding football players, it has been shown that the use in training of semi-inflections with load performed at maximum intensity, will improve their performance in jumps and sprints (Chelly et al., 2009).

In a study, the effects of vertical and horizontal plyometric jumps on sprints among football players were analyzed, revealing the ability of athletes to adapt to this type of training. Thus, it was found that the training with horizontal jumps brings improvements on the speed on short distances of 0-10 m, while the one with vertical jumps will develop the speed on longer distances, of 10-20 m (Loturco et al. 2015a) .

Also among football players strength training has been implemented to improve jumping and sprinting at different age groups, however, this may be inappropriate for young people, as this type of training can limit their growth processes (Garcia-Pinillos et al. , 2014; Loturco et al., 2015a, 2016b; Silva et al., 2015; Behm et al., 2008). In this sense, plyometric training can be applied among young people to improve their performance (Loturco et al., 2015a; Ramirez-Campillo et al., 2015a, b).

Some research points out that the use of resistance exercises in training can have effects on explosive force performance (Cormie, McGuigan & Newton, 2011). The most common in the training process are jumps, due to the relatively low complexity, but to improve the force-speed torque it is recommended to maintain the half-flexion position (McBride, Nimphius & Erickson, 2005; Chelly et al., 2009).

A recent study exploring the particular effects of loaded jump squats and half squats in elite soccer players revealed that both exercises are capable of reducing the decrements in speed-power capacities that commonly occur throughout professional soccer preseasons (Loturco et. Al., 2015).

Another study investigated the effect of plyometric training with loads on the performance obtained among jumps, showing that external loading during plyometric jumps shows a significant increase in explosive ground reaction force (Cronin et al.,, 2014; McKenzie et al., 2014).

Other authors have analyzed the effects of training with and without load on the performance of long jumps and high jumps among football players. Thus, after six weeks of training, improvements in athletes' performance were highlighted, especially in terms of load training (Rosas et al., 2016).

Another study demonstrated the effectiveness of plyometric training with and without load on high jumps among elite football players, the results being significant in practice (Kobal et al., 2017).

It has been reported that loaded jump squats are closely associated with speed tests and actual sprint performance in top-level sprinters (Loturco și colab., 2015a; Loturco și colab., 2015b). Another study showed that maximal strength in half squats is strongly associated with sprinting speed and jumping height in high-level soccer players (Wisloff și colab., 2004).

Another study showed that Jump squat was more connected to sprinting, change-of-direction speed and jumping abilities than half squat in elite rugby sevens players and should be preferred for assessing and possibly training elite athletes needing to improve speed-power related abilities (Loturco și colab., 2017).

Methods

The research analyzed 44 performance women athletes from the first leagues of Romania, divided into 3 groups: football (N=14), handball (N= 13) and rugby (N= 17), according to Table 1.

To evaluate the explosive strength we applied the Squat Jump (football= 34.62 ± 3.66 cm, handball= 37.69 ± 4.27 cm, rugby= 34.53 ± 6.21 cm), the Countermovement Jump (football= 37.01 ± 4.29 cm, handball= 39.21 ± 4.69 cm, rugby= 35.86 ± 6.22 cm), the Free Jump (football= 42.78 ± 5.31 cm, handball= 44.14 ± 3.90 cm, rugby= 39.78 ± 7.04 cm) and the 4 repeated jumps test (football= 1.89 ± 0.38, handball= 2.03 ± 0.35, rugby= 1.91 ± 0.36). Isometric strength was assessed using the handgrip strength test (football= 60.63 ± 10.84 kg, handball= 70.43 ± 9.37 kg, rugby= 65.08 ± 4.88 kg).

Table 1. Physical characteristics of the subjects

	M ± SD		
Variables	**Football (n = 14)**	**Handball (n = 13)**	**Rugby (n = 17)**
Body mass (kg)	57.44 ± 9.12	70.03 ± 8.33	58.81 ± 5.18
Muscle mass (%)	29.01± 2.16	31.06 ± 1.35	31.46 ± 3.45
Body fat (%)	30.09 ± 4.60	28.82 ± 2.34	28.48 ± 5.62

Results

Using Anova One-Way, significant differences were highlighted only in terms of assessing the strength of the palmar flexors (r=0.181, p=0.020), between football and handball players, according to Table 2. This may highlight the fact that between the three groups of subjects there are no significant differences in the values of the explosive force at the level of the lower limbs.

Table 2. The average results of the subjects

	M ± SD		
	Football (n = 14)	**Handball (n = 13)**	**Rugby (n = 17)**
SJ (cm)	34.62 ± 3.66	37.69 ± 4.27	34.53 ± 6.21
CMJ (cm)	37.01 ± 4.29	39.21 ± 4.69	35.86 ± 6.22
FJ (cm)	42.78 ± 5.31	44.14 ± 3.90	39.78 ± 7.04
4J	1.89 ± 0.38	2.03 ± 0.35	1.91 ± 0.36
HS (kg)	60.63 ± 10.84*	70.43 ± 9.37*	65.08 ± 4.88

* p<0.05.

SJ-Squat Jump, CMJ-Countermovement Jump, FJ-Free Jump, 4J-4 repeated jumps test, HS-handgrip strength test

The Pearson correlation showed a direct link between body composition, explosive force and isometric force, for all groups. Regarding the correlations between body composition and explosive and isometric force among football players, the following correlations were highlighted in Table 3. Thus, the correlations between the results of the SJ and FJ tests were highlighted, and regarding the relationship with the body composite, the correlations between the body fat with the FJ and HS samples, and between the muscle mass and the 4J sample were highlighted.

Table 3. Football corelations

	r value					
	Body fat (%)	**Muscle mass (%)**	**SJ (cm)**	**CMJ (cm)**	**FJ (cm)**	**4J**
Body fat (%)						
Muscle mass(%)	-0.42					
SJ (cm)	-0.17	-0.03				
CMJ (cm)	-0.23	0.25	0.85			
FJ (cm)	-0.59**	0.36	0.76***	0.86		
4J	0.32	-0.62**	-0.08	-0.41	-0.34	
HS (kg)	0.62**	0.001	-0.14	-0.02	-0.28	0.33

SJ-Squat Jump, CMJ-Countermovement Jump, FJ-Free Jump, 4J-4 repeated jumps test, HS-handgrip strength test

* p<0.05

Ovidius University Annals, Series Physical Education and Sport / SCIENCE, MOVEMENT AND HEALTH
Vol. XXI, ISSUE 2 Supplement, 2021, Romania
The journal is indexed in: Ebsco, SPORTDiscus, INDEX COPERNICUS JOURNAL MASTER LIST, DOAJ DIRECTORY OF OPEN ACCES JOURNALS, Caby, Gale Cengage Learning, Cabell's Directories

Most of the links between the tests and the body composition were noticed in the case of the handball team, according to Table 4. Muscle mass is correlated with body fat, and also with CMJ and 4J samples. Between the strength evaluation tests, connections are established between CMJ and 4J, FJ and SJ, all of which are correlated with body fat, less FJ.

Table 4. Handball corelations

	r value					
	Body fat (%)	**Muscle mass (%)**	**SJ (cm)**	**CMJ (cm)**	**FJ (cm)**	**4J**
Body fat (%)						
Muscle mass(%)	-0.79***					
SJ (cm)	0.34	-0.42				
CMJ (cm)	0.56**	-0.60**	0.92			
FJ (cm)	0.47	-0.45	0.77***	0.87		
4J	0.64**	-0.68***	0.52	0.58**	0.34	
HS (kg)	0.39	-0.05	0.22	0.30	0.34	-0.16

SJ-Squat Jump, CMJ-Countermovement Jump, FJ-Free Jump, 4J-4 repeated jumps test, HS-handgrip strength test
* p<0.05

According to Table 5, regarding the results of the rugby team, correlations were highlighted only between body fat, muscle mass and the FJ test. In the rest of the results, the existing correlations are insignificant.

Table 5. Rugby corelations

	r value					
	Body fat (%)	**Muscle mass (%)**	**SJ (cm)**	**CMJ (cm)**	**FJ (cm)**	**4J**
Body fat (%)						
Muscle mass(%)	-0.86***					
SJ (cm)	-0.44	0.29				
CMJ (cm)	-0.43	0.26	0.97			
FJ (cm)	-0.52**	0.36	0.91	0.94		
4J	-0.19	0.25	0.28	0.34	0.42	
HS (kg)	-0.20	-0.02	0.07	0.002	0.13	-0.05

SJ-Squat Jump, CMJ-Countermovement Jump, FJ-Free Jump, 4J-4 repeated jumps test, HS-handgrip strength test
* p<0.05

Discussion

The differences between our study groups are insignificant, except for the strength of the palm flexors, where handball players distance themselves from football players. This can be explained by the particularities of each sport, the catch of the ball in handball being done with one hand and frequently, while in football touching the ball with the hand is sanctioned.

For each analyzed group, correlations between the evaluated parameters were highlighted. Body fat is related to the strength and percentage of muscle mass for all our athletes. A significant link is made between the percentage of body fat and muscle mass for handball and rugby players. Thus, it seems that in disciplines with high anaerobic effort the percentage of adipose tissue decreases as a result of increasing muscle mass.

Inactive mass is closely related to the level of strength for each of the three disciplines addressed in this paper. Knowing that body fat has an opposing role for muscle contraction, we can draw the same conclusion based on our results. In football players, the explosive force of the lower limbs, in conditions of elan with the arms, is negatively correlated with the fat in their body, a fact also found in rugby players. Interestingly, the strength of the palm flexors increases when body fat decreases precisely in players who do not use their hands during a sports dispute. Handball players are helped by a low level of adipose tissue when performing a vertical jump without the help of the arms, which is very common in the biomechanics of the game of handball. They also have an improved ground reactivity of the legs when the body composition is optimal.

Furthermore, rugby players no longer record any correlation between results. Instead, football and handball link their muscle mass to the reactivity of their feet on the ground. From here it results that an increased muscle mass will lead to a good speed of departures from the place, which benefits the speed of movement and agility, elements very common in all sports games.

In handball there is also a positive correlation between muscle mass and explosive force starting from isometry, a game-specific feature, because players are often in direct contact with an opponent and immediately start an explosive action.

In general, there is a direct link between the SJ, CMJ and FJ samples, as it requires the lower limbs, under different conditions. This happens to football players, the connection being established between SJ and FJ. The two samples are biomechanically differentiated from the initial position, as well as the execution mode. However, a significant correlation is established for football players, the explosive force starting from a fixed position being interconnected with the dynamic one. This connection is also present in handball players, who also have a correlation between the explosive force and the isolation of the momentum of the arms and the ground reactivity of the legs, the two tests increasing in value in the same direction.

References

Barnes C., Archer DT., Hogg B., Bush M., & Bradley PS., 2014, The evolution of physical and technical performance parameters in the english premier league. Int. J. Sports Med. 35, 1095–1100. doi: 10.1055/s-0034-1375695.

Behm DG., Faigenbaum AD., Falk B., & Klentrou P., 2008, Canadian society for exercise physiology position paper: resistance training in children and adolescents. Appl. Physiol. Nutr. Metab. 33, 547–561. doi: 10.1139/H08-020

Bush M., Barnes C., Archer DT., Hogg B., & Bradley PS., 2015, Evolution of match performance parameters for various playing positionsin the english premier league. Hum. Mov. Sci. 39, 1–11. doi: 10.1016/j.humov.2014. 10.003

Buzek M., Trénink Fotbalu v Zimním Období. In Fotbal a Trénink; Agentura G.D.K. Sport M.: Praha, Czech Republic, 2002; Volume 4, pp. 14–20.

Chelly M.S., Fathloun M., Cherif N., Ben Amar, M., Tabka Z. & Van Praagh E., 2009, Effects of a back squat training program on leg power, jump, and sprint performances in junior soccer players. J Strength Cond Res. 2009; 23: 2241–2249. doi: 10.1519/JSC.0b013e3181b86c40.

Cormie P., McGuigan M.R. & Newton, R.U., 2011, Developing maximal neuromuscular power: part 2—training considerations for improving maximal power production. Sports Med. 2011; 41: 125–146. doi: 10.2165/ 11538500-000000000-00000.

Covic, N., Jeleskovic, E., Alic, H., Rado, I., Kafedzic E., Sporis G., McMaster D.T., Milanovic Z., 2016, Reliability, Validity and Usefulness of 30-15 Intermittent Fitness Test in Female Soccer Players. Front. Physiol. 2016, 7, 510.

Cronin J B., Brughelli M., Gamble P., Brown S R. & McKenzie C., 2014, Acute kinematic and kinetic augmentation in horizontal jump performance using haltere type handheld loading. J. Strength Cond. Res. 28, 1559–1564. doi: 10.1519/JSC.0000000000000312.

Faude O., Koch T. & Meyer T., 2012, Straight sprinting is the most frequent action in goal situations in professional football. J. Sports Sci. 30, 625–631. doi: 10.1080/02640414.2012.665940.

Ford P., De Ste Croix M., Lloyd R., Meyers R., Moosavi M., Oliver J., et al., 2011, The long-term athlete development model: physiological evidence and application. J. Sports Sci. 29, 389–402. doi: 10.1080/02640414.2010.536849.

Garcia-Pinillos F., Martinez-Amat A., Hita-Contreras F., Martinez-Lopez E. J. & Latorre-Roman P.A., 2014, Effects of a contrast training program without external load on vertical jump, kicking speed, sprint, and agility of young soccer players. J. Strength Cond. Res. 28, 2452–2460. doi: 10.1519/JSC.0000000000000452.

Kobal R., Pereira LA., Zanetti V., Ramirez-Campillo R. & Loturco I., 2017, Effects of Unloaded vs. Loaded Plyometrics on Speed and Power Performance of Elite Young Soccer Players. Front. Physiol. 8:742. doi: 10.3389/fphys.2017.00742.

Loturco I., D'Angelo R.A., Fernandes V., Gil S., Kobal R., Abad CCC., et al., 2015, Relationship between sprint abil ity and loaded/unloaded jump tests in elite sprinters. J Strength Cond Res. 2015; 29: 758–764. doi: 10. 1519/JSC.0000000000000660.

Loturco I., Pereira L. A., Kobal R., Maldonado T., Piazzi A F., Bottino A., et al., 2016b, Improving sprint performance in soccer: effectiveness of jump squat and olympic push press exercises. doi: 10.1371/journal.pone.0153958.

Loturco I., Pereira L. A., Kobal R., Zanetti V., Kitamura K., Abad CC., et al., 2015a, Transference effect of vertical and horizontal plyometrics on sprint performance of high-level U-20 soccer players. J. Sports Sci. 33, 2182–2191. doi: 10.1080/02640414.2015.1081394.

Loturco I., Pereira L.A., Cal Abad CC., D'Angelo RA., Fernandes V., Kitamura K., et al., 2015, Vertical and horizon tal jump tests are strongly associated with competitive performance in 100-m dash events. J Strength Cond Res. 2015; 29: 1966–1971. doi: 10.1519/JSC.0000000000000849.

Loturco I., Pereira LA., Kobal R., Zanetti V., Gil S., Kitamura K., et al., 2015, Half-squat or jump squat training under optimum power load conditions to counteract power and speed decrements in Brazilian elite soc cer players during the preseason. J Sports Sci. 2015; 33: 1283–1292. doi: 10.1080/02640414.2015.

Loturco I., Pereira LA., Moraes JE., Kitamura K., Cal Abad CC., Kobal R., et al., 2017, Jump-Squat and Half-Squat Exercises: Selective Influences on Speed-Power Performance of Elite Rugby Sevens Players. doi:10.1371/journal.pone.0170627.

Loturco I., Ugrinowitsch C., Roschel H., Lopes Mellinger A., Gomes F., Tricoli V., et al., 2013, Distinct temporal organizations of the strength- and power-training loads produce similar performance improvements. J Strength Cond Res. 2013; 27: 188–194. doi: 10.1519/JSC.0b013e3182503807.

Loturco I., Ugrinowitsch C., Roschel H., Tricoli V., Gonzalez-Badillo JJ., 2013, Training at the optimum power zone produces similar performance improvements to traditional strength training. J Sports Sci Med. 2013; 12: 109–115. PMID: 24149733 .

Loturco I., Winckler C., Kobal R., Cal Abad CC., Kitamura K., Verissimo AW., et al., 2015, Performance changes and relationship between vertical jump measures and actual sprint performance in elite sprinters with visual impairment throughout a Parapan American games training season. Front Physiol. 2015; 6: 323. doi: 10.3389/fphys.2015.00323 PMID: 26594181.

McBride J.M., Nimphius S. & Erickson, TM., 2005, The acute effects of heavy-load squats and loaded counter movement jumps on sprint performance. J Strength Cond Res. 2005; 19: 893–897. doi: 10.1519/R 16304.1 PMID: 16287357 .

McKenzie C., Brughelli M., Gamble P. & Whatman C., 2014, Enhancing jump performance with handheld loading. Strength Cond. J. 36, 32–38. doi: 10.1519/SSC.0000000000000041.

Michalsik LB., Aagaard P. & Madsen K., 2013, Locomotion characteristics and match-induced impairments in physical performance in male elite team handball players. Int J Sports Med, 2013; 34: 590–599.

Nibali ML., Chapman DW., Robergs R.A. & Drinkwater E.J., 2013, A rationale for assessing the lower-body power profile in team sport athletes. J Strength Cond Res. 2013; 27: 388–397. doi: 10.1519/JSC. 0b013e3182576feb PMID: 22505130.

Pacholek M. & Zemková E., 2020, Effect of Two Strength Training Models on Muscle Power and Strength in Elite Women's Football Players, Sports 2020, 8, 42; doi:10.3390/sports8040042.

Pardos-Mainer E., Casajus J., Gonzalo-Skok O., 2020, Effects of Combined Strength and Power Training on Physical Performance and Interlimb Asymmetries in Adolescent.

Int. J. Sports Physiol. Perform. 2020, 20, 1–9.

Pardos-Mainer E., Casajus JA., Gonzalo-Skok O., 2019, Adolescent female soccer players' soccer-specific warm-up effects on performance and inter-limb asymmetries. Biol. Sport 2019, 36, 199–207.

Pardos-Mainer E., Lozano D., Torrontegui-Duarte M., Cartón Llorente A., Roso-Moliner A., 2021, Effects of Strength vs. Plyometric Training Programs on Vertical Jumping, Linear Sprint and Change of Direction Speed Performance in Female Soccer Players: A Systematic Review and Meta Analysis. Int. J. Environ. Res. Public Health 2021, 18, 401. https://doi.org/ 10.3390/ijerph18020401.

Ramirez-Campillo R., Alvarez C., García-Pinillos F., Gentil P., Moran J., Pereira LA., Loturco I., 2019, Plyometric training in young male soccer players: Potential e_ect of jump height. Pediatric. Exerc. Sci. 2019, 31, 306–313.

Ramirez-Campillo R., Burgos CH., Henriquez-Olguin C., Andrade DC., Martinez C., Alvarez C., et al., 2015b, Effect of unilateral, bilateral, and combined plyometric training on explosive and endurance performance of young soccer players. J. Strength Cond. Res. 29, 1317–1328. doi: 10.1519/JSC.0000000000000762

Ramirez-Campillo R., Gallardo F., Henriquez-Olguin C., Meylan, CM., Martinez C., Alvarez C., et al., 2015a, Effect of vertical, horizontal, and combined plyometric training on explosive, balance, and endurance performance of young soccer players. J. Strength Cond. Res. 29, 1784–1795. doi: 10.1519/JSC.0000000000000827 .

Rosas F., Ramirez-Campillo R., Diaz D., Abad-Colil F., Martinez-Salazar C., Caniuqueo A., et al., 2016, Jump training in youth soccer players: effects of haltere type handheld loading. Int. J. Sports Med. 37, 1060–1065. doi: 10.1055/s-0042-111046.

Shalfawi SA., Haugen T., Jakobsen TA., Enoksen E., Tonnessen E., 2013, The effect of combined resisted agility and repeated sprint training vs. strength training on female elite soccer players. J. Strength Cond. Res. 2013, 27, 2966–2972.

Silva JR., Nassis G P. & Rebelo A., 2015, Strength training in soccer with a specific focus on highly trained players. Sports Med. Open 1:17. doi: 10.1186/s40798-015-0006-z.

Williams C A., 2016, Trainability of young athletes: short-term goals or long term mission? Pediatr. Exerc. Sci. 28, 485–487. doi: 10.1123/pes.2016-0215.

Wisloff U., Castagna C., Helgerud J., Jones R. & Hoff, J., 2004, Strong correlation of maximal squat strength with sprint performance and vertical jump height in elite soccer players. Br J Sports Med. 2004; 38: 285–288. doi: 10.1136/bjsm.2002.002071 PMID: 15155427