

The Effect of Hamstring Eccentric Strength and Asymmetry on Acceleration and Vertical Jump Performance in Professional Female Soccer Players

El efecto de la fuerza excéntrica y la asimetría de los isquiotibiales sobre la aceleración y el rendimiento del salto vertical en jugadoras de fútbol profesionales

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Abstract. The aim of this study was to investigate the relationship between eccentric hamstring muscle strength and acceleration and vertical jump in professional female soccer players. Twentieth professional female soccer players actively playing soccer participated in the study voluntarily with age (arithmetic mean \pm standard deviation) 18.31 ± 5.97 . The NORDBORD device was used to measure the participants' hamstring eccentric force output, the Smartspeed™ Contact Mat was used for vertical jump performance and the FUSIONSPTS Smartspeed™ PRO photocell (Fusion Sport, Queensland, Australia) was used for 0-20m sprint performance measurements. When the relationship between eccentric hamstring strength parameters, vertical jump and sprint performance of the participants was analyzed, no significance was found. It is seen that there is a negative relationship between VJ and 0-5m at a moderate level ($r = -.586$, $p = .022$) and a negative relationship between VJ and 0-20m at a high level ($r = -.793$, $p = .000$). Since the studies examining the relationship between Hamstring Strength and Sprint performance are limited in number, it is not possible to reach a definite conclusion, more comprehensive and more studies are needed.

Key words: Hamstring, Eccentric, Sprint, Acceleration, Vertical Jump, Football players.

Resumen. El objetivo de este estudio fue investigar la relación entre la fuerza excéntrica de los músculos isquiotibiales y la aceleración y el salto vertical en jugadoras de fútbol profesionales. Participaron voluntariamente en el estudio vigésimas futbolistas profesionales que practicaban activamente fútbol con una edad (media aritmética \pm desviación estándar) de $18,31 \pm 5,97$. Se utilizó el dispositivo NORDBORD para medir la producción de fuerza excéntrica de los isquiotibiales de los participantes, la estera de contacto Smartspeed™ se utilizó para el rendimiento del salto vertical y la fotocélula FUSIONSPTS Smartspeed™ PRO (Fusion Sport, Queensland, Australia) se utilizó para Mediciones de rendimiento en sprints de 0 a 20 m. Cuando se analizó la relación entre los parámetros de fuerza excéntrica de los isquiotibiales, el salto vertical y el rendimiento de sprint de los participantes, no se encontró significancia. Se observa que existe una relación negativa entre VJ y 0-5m en un nivel moderado ($r = -.586$, $p = .022$) y una relación negativa entre VJ y 0-20m en un nivel alto ($r = -.793$, $p = -.000$). Dado que los estudios que examinan la relación entre la fuerza de los isquiotibiales y el rendimiento en el sprint son limitados en número, no es posible llegar a una conclusión definitiva; se necesitan más estudios y más exhaustivos.

Palabras clave: Isquiotibial, Excéntrica, Sprint, Aceleración, Salto vertical, Jugadoras de futbol.

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Introduction

A review of the major soccer leagues around the world has shown that sprint distance, ball speed and the number of sprints per match have increased in recent years (Barnes et al., 2014; Wallace et al., 2014). Sprinting, and more specifically sprint acceleration, is an important component of performance in many sports such as athletics, soccer and rugby (Stølen et al., 2005). These high-intensity moments (e.g., very short sprints) occur at decisive moments, such as tackles, offensive or defensive actions, and have the potential to significantly influence the outcome of competitions (Faude et al., 2012; Sasaki et al., 2015). In every sport, the maximum rate of acceleration occurs in the early stages of sprinting (Akenhead et al., 2013; Standing & Maulder, 2017). From this information, it is possible to conclude that the capacity to reach higher speeds over very short distances (e.g. ≤ 5 -m) is a critical component in achieving success (Barnes et al., 2014; Bush et al., 2015; Faude et al 2012, Di Salvo et al., 2009).

The current trends in the practice of sports training specific to football, focus on the integrated approach to sports training by combining the momentum exercises with those specific to CMJ, unilateral and bilateral (Magallanes, 2022).

The sports training programs require coaches to design exercise programs, correlated with the sports particularities and with the latest recommendations derived from scientific research in the field (Firmansyah, et al. 2023; Fonseca et al., 2021).

From a mechanical perspective, increased eccentric hamstring force and neuromuscular activity can improve sprint performance. Several studies have demonstrated the important role of the hip extensors (gluteal and hamstring muscles) in running performance (Wiemann & Tidow, 1995; Bartlett et al., 2014; Schache et al., 2014). This is because in sprint mechanics, the hamstring muscles decelerate knee extension in the swing phase and then generate horizontal forces through hip extension in the stance phase (Morin et al., 2015; Miras Moreno, 2020). Gains in eccentric hamstring strength induced by various exercise modalities have previously shown promising effects on sprint performance in soccer players (Asking et al., 2003; Mendiguchia et al., 2015). Acceleration is the first 10 meters of sprinting activity (Hewitt et al., 2011; Little, 2005.) In addition, research using other methods to increase eccentric hamstring strength has indeed reported improvements in jump and sprint performance (de Hoyo et al., 2015; Malek et al., 2024). Jumping ability has also been associated with

sprinting performance (Wisloff et al., 2004, Kukric et al., 2022).

The technique of the football game consists of sometimes sudden changes of direction, sprints and vertical jumps that involve an eccentric and concentric effort in the muscles of the lower limbs (Buhry et al., 2022, Badau et al., 2018). The isokinetic elements in making the vertical jumps, specific to the football game, performed at speed, assume an almost maximum muscle strength, due to the load and the dynamics of the movement (Badau & Badau, 2022; Soyal et al., 2023). According to the specialists, the following are involved in the vertical jump: the strength of the leg muscles, the speed of muscle force generation, the speed of contraction, the intramuscular coordination and the efficiency of the muscle stretching-shortening system (Zileli & Söyler, 2021). The improvement of vertical jump values, both in team and individual sports, is determined by the specific methodology applied in accordance with the motor level of the athletes and the specific demands of the practiced sport (Badau et al., 2018; Bishop et al., 2021). In practice, the specialists in physical training specific to football, with an emphasis on the development of the strength of the lower segments and the improvement of plyometrics, the emphasis is mainly achieved by a dominance of load control, with positive effects, if it involves an individualization according to the potential of each athlete (Falces-Prieto et al., 2021).

However, studies investigating the effect of Hamstring Eccentric Muscle Strength on acceleration performance are lacking. The aim of this study was to investigate the effect of hamstring eccentric muscle strength on acceleration and vertical jump performance in professional female soccer.

Material and Method

Participants

20 female soccer players actively playing in the 2nd Turkish women's soccer league participated in the present study. The female subjects included in the study had an average age of 18.31, with an average height of 1.59 m and an average body weight of 48.8 kg. After the individual questioning, all the athletes of the study show a dominant right foot. Inclusion criteria: to be legitimized at the level of the II football league, healthy, without injuries. Before performing the tests, all subjects were informed about the testing procedure, giving their verbal consent to participate voluntarily.

Study design

A cross-sectional study design was used in this study, following the evaluation of certain parameters of the vertical jump in professional female soccer athletes. All methods were explained to all participating individuals. The soccer players performed 10 minutes of dynamic lower and upper extremity warm-up exercises as a team before the tests.

Data Collection Tools

The following devices were used in the present study:

Table 1.

Centralizer of results recorded in applied tests

Vertical Jump Test - SmartSpeed Contact Mat (Reeve & Tyler, 2013) was used to measure vertical jump parameters. In the test, the athlete was asked to make the highest upward jump in a half-squat position (knee angle 90°) with hands on waist. It was evaluated using the average of the two best measurements.

NORDBORD Test- have recently developed a new field-testing device for the assessment of hamstring eccentric strength (Opar et al. 2013), called Nordbord, based on the widely used Scandinavian hamstring exercise. The Nordbord allows the assessment of maximum eccentric knee flexor force (i.e. the force in Newtons captured by load cells used as a measure of force) and inter-limb imbalances in a short period of time. Assessment of eccentric hamstring force was evaluated using a NordBord device (Vald Performance, Newstead, Australia) sampling at a frequency of 50 Hz. Parameters targeted by the use of the NordBord device were: the maximum force of the right leg (R max Force), the maximum force of the left leg (L max Force), respectively the arithmetic average of the force for the right leg (R Average Force) and the left leg (L Average Force), as well as the asymmetry (%). Testing the asymmetry between the executions with the right and left legs, involves performing a Counter Movement Jump (CMJ) initially on two legs and then on each leg, for the accuracy of the testing that takes into account two parameters: force absorption and force production, the limit of which is < 10% difference between L and R (VALD Performance, 2022; Van den Tillaar et al., 2017).

Smart Speed 0-20 Meter Sprint Test - to determine acceleration, the entire FUSIONSPORTS Smartspeed™ PRO photocell (Fusion Sport, Queensland, Australia) was used, which was designed with a gate at 5 meter intervals in a 20 meter area, and for acceleration, it was recorded the result in the first 10 meter sprint. Each player performed two trials and the highest value was taken as reference (Coşan et al., 2002)

Statistics Analysis

The data obtained from the research were analyzed using SPSS 22.0 software aiming at the following parameters: arithmetic means (X), standard deviation (SD), Variance and Kurtosis. Simple Linear Regression Analysis and Pearson Correlation Analysis was used to examine the relationship between variables. The strength of the correlation was determined based on the value of r: $r \leq 0.1$, trivial; $0.1 < r \leq 0.3$, small; $0.3 < r \leq 0.5$, medium; $0.5 < r \leq 0.7$, large; $0.7 < r \leq 0.9$, very large; and $r > 0.9$, almost perfect (Cohen, 1988).

Results

In Table 1, the arithmetic means of the main parameters recorded in the applied tests are presented, and when interpreting the results, we referred to the minimum and maximum values that were not presented in the table.

Tests	Parameters	X	SD	Variance	Kurtosis
Smart Speed 0-20 Meter Sprint Test	Acceleration 0-5m (m/s)	1.078	.073	.006	-.840
	Acceleration 0-20 (m/s)	3.374	.180	.035	-.337
	Acceleration 0-10m (m/s)	2.220	.136	.019	1.451
Vertical Jump Test	VJ (cm)	3.238	5.245	33.551	.446
NORDBORD Test	L Max Force (N)	223.716	47.618	2362.193	-.209
	R Max Force (N)	240.950	46.926	2464.858	-.578
	L Average Force (N)	215.875	45.796	2166.874	-.973
	R Average Force (N)	222.270	42.238	1915.296	-.739
	Assymetry (%)	6.862	6.668	43.943	.476

X- Arithmetic mean, SD- Standard deviation, VJ-Vertical jump

The minimum values recorded for acceleration were: for 0-5m, 0.94m/s playing as a forward, 0-10m, 2.05m/s playing as a stopper and at 0-20m, 3.00m/s an attacking player. The maximum values were: 0-5m, 1.18m/s a player on the stopper position, 0-10m, 2.56m/s center player, respectively at 0-20m, 3.70m/s also center player. It is found that the players in the center line have a capacity to accelerate below those who play in the attack line and take over the ball. In the VJ parameter, the minimum value

was 20.12 for center players and the maximum value was 41.55cm, forward. For the maximum strength of the right leg: minimum 160 for the stopper position and maximum 302(N) for the defender position. For the left foot, minimum 161, midfielder player, maximum 299 defensive player. The asymmetry falls within optimal parameters <10% difference between L and R. Kurtosis values fell between -.840 and 1.451, which indicates a normal distribution of the data (Table 1).

Table 2. Pearson Correlation Analysis

Parameters	Assymetry	Acceleration 0-5m	Acceleration 0-20m	Acceleration 0-10m	VJ	L Average Force	R Average Force
Assymetry	r	1	.026	-.106	.072	-.274	-.041
Acceleration 0-5m	r		1	.698**	.737**	-.586*	.164
Acceleration 0-20m	r			1	.423	-.793**	-.401
Acceleration 0-5m	r				1	-.312	.094
VJ	r					1	.228
L Average Force	r						1
R Average Force	r						

*Large, ** Very large, *** Almost perfect; VJ – Vertical jump, L- Left, R – Right.

Table 3. Simple Linear Regression Analysis for Acceleration on 0-5m; 0-10 m; 0-20 m, Predictions

Tests	B	Standard error	β	t	p
0-5 m- Assymetry	1.077	.029		37.598	.000
	.000	.003	.026	.095	.925
R= .072 R ² = .005 F= 0,67 p<.000					
0-10 m- Assymetry	2.211	.053		41.426	.000
	.001	.006	.072	.259	.800
R= .072 R ² = .005 F= 0,67 p<.000					
0-20 m- Assymetry	3.394	.070		48.235	.000
	-.003	.007	-.106	-.383	.708
R= .106 R ² = .011 F= .147 p<.000					
0-5 m- VJ	1.326	.096		13.793	.000
	-.008	.003	-.586	-2.608	.022*
R= .586 R ² = .343 F= 6.800 p<.000					
0-10 m- VJ	2.467	.210		11.721	.000
	-.008	.007	-.312	-1.186	.257
R= .312 R ² = .098 F= 1.407 p<.000					
0-20- VJ	4.200	.179		23.507	.000
	-.027	.006	-.793	-4.687	.000*
R= .793 R ² = .628 F= 21.967 p<.000					

* Semnificativ statistic p<.05; B- the intercept, t—Student test value; p—Level of probability, R² - the regression coefficient, F- Test value, VJ – Vertical jump

According to Table 2, we identified statistically significant correlations between Acceleration 0-5m with: Acceleration 0-20m, Acceleration 0-10m and with VJ, reported to the reference value of the threshold of statistical significance. The power of the linear association is very large between the two acceleration variants, it is directly proportional, showing a positive direction. Between the acceleration on 0-5m with VJ the correlation is inversely proportional, indicating a negative direction,

with a large correlation. VJ correlates very large with acceleration on 0-20m, r= -.793, inversely proportional. Another statistically significant correlation was recorded between L Average Force and R Average Force, indicating a directly proportional positive association, almost perfect (Table 2). No significant correlations were recorded between the other parameters of the applied tests, for p< .05.

Analyzing the results in Table 3 following the application of simple linear regression analysis, where acceleration variables were used to predict VJ and asymmetry measurements, they were found to be predictive of VJ only. Asymmetry was not predicted by acceleration variables, with results not statistically significant. The analysis of the results reveals that the 0-5 m acceleration is a predictor for VJ (R²= 0.343, p<0.002). Also, 0-20m acceleration was found to be a predictor for VJ (R²= 0.628, p<0.000). Analyzing the values of the t-statistic index, we find that they are large, which means that our results are unlikely to be due to random incidence.

The most relevant aspect that was found is the fact that the presented model is a good fit, for the observed data, the values of the p index being statistically significant (p<0.001).

Discussion

When our study was examined, the significance of right and left leg hamstring eccentric muscle strength with 0-5m,

0-10m, 0-20m and vertical jump performances was not found. The analysis of the results shows statistically significant correlations between the three variants of acceleration and VJ, as well as between L Average Force and R Average Force. No significant correlations were found between asymmetry and the other targeted parameters (for $p < .05$). The application of linear regression highlighted that the asymmetry was not predicted by the acceleration variables, with statistically insignificant results. Vj is the acceleration prediction only on 0-5 m and 0-20 m.

Looking at the studies on the relationship between eccentric hamstring strength and sprint in the literature, a study by (Mendiguchia et al., 2020) divided the participants into 3 groups as a group doing Nordic Hamstring Exercise that increases eccentric hamstring muscle strength, a group doing sprint training and a group doing only specific football training and showed that the group doing.

Nordic Hamstring Exercise and the group doing specific football training showed less improvement in sprint performance compared to the group doing sprint training in their tests 6 weeks later. Freeman et al. (2019) in a study with twenty-eight adolescent athletes, participants were randomly assigned to a NHE training or sprint training group. They completed an eccentric hamstring strength assessment to assess acceleration (acceleration) and maximum speed, and a 40 m sprint. The NHE group reported insignificant improvements in sprint performance, while the sprint training group experienced a moderate improvement, particularly in maximum speed. It was concluded that a four-week sprint training block may provide benefits in terms of both injury prevention and performance enhancement. de Hoyo et al. (2015) in their study with thirty-six young players, participants were randomly assigned to an experimental or control group. Participants performed an eccentric overload training program (3-6 sets of 6 repetitions) for 1 or 2 sessions per week for 10 weeks.

In terms of performance, the eccentric-based program led to a reduction in the incidence and severity of muscle injuries and showed improvements in common soccer tasks such as jump performance and linear sprint speed. Krommes et al., (2017) investigated sprint performance using a 10-week injury prevention Nordic Hamstring Exercise protocol and reported improvement in 10 m sprint performance. Previous studies have focused on determining the plyometric capacity of athletes in various conditions, using various tests, for athletes in individual and team sports, the results registering positive effects, but correlated with certain kinetic parameters were not always statistically significant (Kotsakis et al, 2023; Fernández-Galván et al., 2024). Güllü et al (2021) examined the effect of 6-week eccentric hamstring strength training on vertical jump and sprint performance in athletes in 19 participants, with an experimental group of 10 and a control group of 9. Nordic hamstring training was found to improve both sprint and vertical jump performance at a low to moderate level. As a result, it was seen that there was no relationship between

Right and Left Leg Eccentric Hamstring Strength and Acceleration and Vertical Jump Performance. Previous studies mention that for the specific training of sportswomen aiming at the parametric improvement of the vertical jump, it is recommended to select the means of action, implemented according to the motor level and the level of development of the motor and functional capacity (Badau et al., 2022; Zaharie et al, 2023; Magallanes et al., 2022).

The asymmetry of the legs of soccer players, in the present study, fell within the allowed limit. Previous studies reflect the fact that female players with a right foot prevalence show reduced weights of the direction and magnitude of the asymmetry (Bishop et al., 2019; Bishop et al., 2021). A previous study looking at vertical jump performance, comparing dominant and non-dominant legs, in soccer players, found significant differences ($p < 0.05$) between dominant and non-dominant legs in the imposing phase of the movement and statistically insignificant variables in the phase of landed (Yanci, J., & Camara, J., 2016), this finding aligns with the results of our study that focused on the vertical jump in all specific phases. Previous studies on female subjects regarding leg asymmetry were also carried out in the game of badminton, handball, volleyball (Wirawan et al., 2014; Tupinambá, 2023; Vila Suarez et al, 2023).

Physical training with an emphasis on plyometrics is known for its positive positive influences in vertical and horizontal jumping (Fonseca et al., 2020), with connotations regarding the ability to accelerate and sprint (Falces-Prieto et al., 2021), it improves the muscular tendency in the release of maximum force in short time units, offering a motor and technical advantage in team sports in certain phases of the game (Sánchez-Sixto & Floría-Martín, 2017).

The present study has the following relevant limits identified by us, namely: the study included only professional subjects from the 2nd league, the limited number of subjects included in the study, the study took into account only a female sample, no training program was applied specifically, which would offer the possibility of comparison between tests.

Conclusion

The results recorded and statistically analyzed in professional soccer athletes, regarding the relationship between the eccentric strength parameters of the hamstring, the vertical jump and the sprint performance of the participants, did not record significant values. A negative relationship was found between VJ and 0-5m at a moderate level ($r = -.586$, $p \leq .022$) and a negative relationship between VJ and 0-20m at a high level ($r = -.793$, $p \leq .000$). Another statistically significant correlation was recorded between the average force L and the average force R, directly proportional, with a linear positive direction, almost perfectly. The asymmetry of the legs falls within the optimal limits, not influencing the other targeted parameters. In linear regressions where acceleration variables were used

to predict VJ and asymmetry measurements, they were found to be predictive only for VJ. Since the studies examining the relationship between Hamstring Strength and sprint performance are limited in number, the analogy with results from other previous studies is difficult, in conclusion we consider that additional studies are needed on several categories of subjects and practiced sports.

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Nothing to declare.

Conflict of interest

The authors declare no conflict of interest.

References

- Akenhead, R., Hayes, P. R., Thompson, & K. G., French, D. (2013). Diminutions of acceleration and deceleration output during professional football match play. *J Sci Med Sport*, 16, 556–561. <https://doi.org/10.1016/j.jsams.2012.12.005>
- Asking, C., Karlsson, J., & Thorstensson, A. (2003). Hamstring injury occurrence in elite soccer players after preseason strength training with eccentric overload. *Scandinavian journal of medicine & science in sports*, 13(4), 244-250. <https://doi.org/10.1034/j.1600-0838.2003.00312.x>
- Badau, D., & Badau, A. (2022). Optimizing Reaction Time in Relation to Manual and Foot Laterality in Children Using the Fitlight Technological Systems. *Sensors*, 22(22), 8785. <https://doi.org/10.3390/s22228785>
- Badau, D., Badau, A., & Clipa, A. (2018). Interaction Between Values of Anthropometric Body and Static Balance Related to the Characteristics of the Three Plastic Fitness Equipment. *Revista de materiale plastice*, 55(4), 600-602.
- Badau, D., Badau, A., Ene-Voiculescu, C., Larion, A., Ene-Voiculescu, V., Mihaila, I., Fleancu, J. L., Tudor, V., Tifrea, C., Cotovanu, A. S., & Abramiuc, A. (2022). The Impact of Implementing an Exergame Program on the Level of Reaction Time Optimization in Handball, Volleyball, and Basketball Players. *International Journal of Environmental Research and Public Health*, 19(9), 5598. <https://doi.org/10.3390/ijerph19095598>
- Badau, D., Talaghir, L. G., Rus, V., & Badau, A. (2018). The impact of the needs and roles of nutrition counselling in Sport. *Человек. Спорт. Медицина, Human. Sport. Medicine*, 18(2), 88-96. DOI: 10.14529/hsm180208
- Barnes, C., Archer, D. T., Hogg, B., Bush, M., & Bradley, P. S. (2014). The evolution of physical and technical performance parameters in the English Premier League. *Int J Sports Med*. 35, 1095–1100. <https://doi.org/10.1055/s-0034-1375695>
- Bartlett, J. L., Sumner, B., Ellis, R. G., & Kram, R. (2014). Activity and functions of the human gluteal muscles in walking, running, sprinting, and climbing. *Am. J. Phys. Anthropol.* 153, 124–131. <https://doi.org/10.1002/ajpa.22419>
- Bishop, C., Brashill, C., Abbott, W., Read, P.; Lake, J., & Turner, A. (2019). Jumping Asymmetries Are Associated with Speed, Change of Direction Speed, and Jump Performance in Elite Academy Soccer Players. *J. Strength Cond. Res.* 35, 1841–1847. <https://doi.org/10.1519/jsc.0000000000003058>
- Bishop, C., Coratella, G., & Beato, M. (2021). Intra- and Inter-Limb Strength Asymmetry in Soccer: A Comparison of Professional and Under-18 Players. *Sports*, 9(9), 129. <https://doi.org/10.3390/sports9090129>
- Bukry, S. A., Raja Azidin, M. R. F., Justine, M., & Manaf, H. (2022). Effects of Short Duration-High Intensity Soccer Fatigue Simulation on Dynamic Balance and Lower Limb Isokinetic Strength in Youth Soccer Players. *Annals of Applied Sport Science*, 10 (2), 0–0. <https://doi.org/10.52547/aassjournal.1033>
- Bush, M., Barnes, C., Archer, D. T., Hogg, B., & Bradley, P. S. (2015). Evolution of match performance parameters for various playing positions in the English Premier League. *Hum Mov Sci.* 39, 1–11. <https://doi.org/10.1016/j.humov.2014.10.003>
- Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences*. 2nd ed. Hillsdale, NJ: Lawrence Erlbaum Associates.
- Coşan, F., Demir, A., Mengütay, S. (2002). Türk Çocuklarının Fiziki Uygunluk Normları. İstanbul: Olimpiyat Oyunları Hazırlık ve Düzenleme Kurulu Eğitim Yayınları Yayın, 1.
- de Hoyo, M., Pozzo, M., Sañudo, B., Carrasco, L., Gonzalo-Skok, O., Domínguez-Cobo, S., & Morán-Camacho, E. (2015). Effects of a 10-week in-season eccentric-overload training program on muscle-injury prevention and performance in junior elite soccer players. *International journal of sports physiology and performance*, 10(1), 46-52. <https://doi.org/10.1123/ijssp.2013-0547>
- Di Salvo, V., Gregson, W., Atkinson, G., Tordoff, P., & Drust, B. (2009). Analysis of high intensity activity in Premier League soccer. *Int J Sports Med*. 30, 205–212. <https://doi.org/10.1055/s-0028-1105950>
- Falces-Prieto, M., Raya-González, J., Sáez de Villarreal, E., Rodicio-Palma, J., Iglesias-García, F. J., & González Fernández, F. T. (2021). 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 (Effects of combined plyometric and sled training on vertical jump and linear speed performan. *Retos*, 42, 228–235. <https://doi.org/10.47197/retos.v42i0.86423>
- 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. <https://doi.org/10.1080/02640414.2012.665940>
- Fernández-Galván, L., M., Casado, A., & Domínguez, R. (2024). Evaluación y prescripción del salto vertical y horizontal en futbolistas. Revisión narrativa (Assessment and prescription of vertical and horizontal jumping in soccer players. Narrative review). *Retos*, 52, 410–420. <https://doi.org/10.47197/retos.v52.101834>
- Firmansyah, A., Handayani, T., Ayubi, N., Ardha, M. A. A., Widodo, A., Oktavianto, D., Preasetya, M. R. A., & Bayu Putro, A. (2023). Tecnología para la detección del riesgo de lesión por distensión del tendón de la corva (HIS) a través de la prueba de fuerza muscular: revisión sistemática (Technology For Screening Potency Risk Hamstring Strain Injury (HIS) Through Muscle Strength Test: Systematic Review). *Retos*, 50, 613–619. <https://doi.org/10.47197/retos.v50.99066>

- Fonseca, R. T., Castro, J. B. P. de, Santos, A. O. B. dos, Lopes, G. C., Nunes, R. de A. M., & Vale, R. G. de S. (2021). 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: una revisión sistemática. *Retos*, 39, 981–987. <https://doi.org/10.47197/retos.v0i39.82254>
- Freeman, B. W., Young, W. B., Talpey, S. W., Smyth, A. M., Pane, C. L., & Carlon. T. A. (2019). The effects of sprint training and the Nordic hamstring exercise on eccentric hamstring strength. *J Sports Med Phys.* 59(7), 1119-1125. <https://doi.org/10.23736/s0022-4707.18.08703-0>
- Gherghel, A., Badau, D., Badau, A., Moraru, L., Manolache, G. M., Oancea, B. M., Tifrea, C., Tudor, V., & Costache, R. M. (2021). Optimizing the Explosive Force of the Elite Level Football-Tennis Players through Plyometric and Specific Exercises. *International Journal of Environmental Research and Public Health*, 18(15), 8228. <https://doi.org/10.3390/ijerph18158228>
- Hewitt, J., Cronin, J., Button, C., & Hume, P. (2011). Understanding Deceleration in Sport. *J Strength Cond Res.*, 33, 47-52. DOI: 10.1519/SSC.0b013e3181fbd62c
- Kotsakis, P., Michailidis, Y., Svygnos, G., Mandroukas, A., Gissis, I., & Metaxas, T. (2023). Correlation between performance in repeated sprints and performance in other laboratory and field fitness tests in female soccer athletes. *TRENDS in Sport Sciences*, 30(4), 143-155. DOI: 10.23829/TSS.2023.30.4-2
- Krommes, K., Petersen, J., Nielsen, M. B., Aagaard, P., Hölmich, P., & Thorborg, K. (2017). Sprint and jump performance in elite male soccer players following a 10-week Nordic Hamstring exercise Protocol: a randomised pilot study. *BMC research notes*, 10, 1-6. <https://doi.org/10.1186/s13104-017-2986-x>
- Kukric, A., Joksimovic, M., Petrovic, M., Zlojutro, N., & Dobras, R. (2022). Relations of muscle strength and body mass when performing different vertical jumps. *TRENDS in Sport Sciences*, 29(1), 19-26. DOI: 10.23829/TSS.2022.29.1-3
- Little, T., & Williams, A. G. (2005). Specificity of acceleration, maximum speed, and agility in professional soccer players. *J Strength Cond Res.*, 19(1), 76-8. <https://doi.org/10.1519/14253.1>
- Magallanes, A., Magallanes, C., Parodi Feye, A. S., & González-Ramírez, A. (2022). Transferencia de un programa de entrenamiento de fuerza al sprint y al salto vertical en futbolistas juveniles: sentadillas vs. estocadas (Transfer of a resistance training program to sprinting and vertical jump in youth soccer players: squats vs. lunges). *Retos*, 46, 972–979. <https://doi.org/10.47197/retos.v46.93296>
- Malek, N. F. A., Nadzalan, A. M., Tan, K., Nor Azmi, A. M., Krishnan Vasanthi, R., Pavlović, R., Badau, D., & Badau, A. (2024). The Acute Effect of Dynamic vs. Proprioceptive Neuromuscular Facilitation Stretching on Sprint and Jump Performance. *Journal of Functional Morphology and Kinesiology*, 9(1), 42. <https://doi.org/10.3390/jfmk9010042>
- Mehmet Gulu, M., & Doğan, A. A. (2021). The Effect of 6 Week Nordic Hamstring Exercise on Sprint and Jumping Performance. *Spor Bilimleri Araştırmaları Dergisi*, 6(2), 421-430. <https://doi.org/10.25307/jssr.978869>
- Mendiguchia, J., Conceição, F., Edouard, P., Fonseca, M., Pereira, R., Lopes, H., Morin, J. B., & Jiménez-Reyes P. (2020). Sprint versus isolated eccentric training: Comparative effects on hamstring architecture and performance in soccer players. *Plos one*, 15(2), e0228283. <https://doi.org/10.1371/journal.pone.0228283>
- Mendiguchia, J., Martínez-Ruiz, E., Morin, J. B., & Samozino, P. (2015). Effects of hamstring emphasized neuromuscular training on strength and sprinting mechanics in football players. *Scandinavian Journal of Medicine and Science in Sports*, 25(6), e621–e629. <https://doi.org/10.1111/sms.12388>
- Miras Moreno, S. (2020). La altura del salto en contramovimiento como instrumento de control de la fatiga neuromuscular. Revisión sistemática (Counter-movement Jump height as a means to monitor neuromuscular fatigue. Systematic Review). *Retos*, 37, 820–826. <https://doi.org/10.47197/retos.v37i37.73302>
- Morin, J. B., Gimenez, P., Edouard, P., Arnal, P., & Brughelli M. (2015). Sprint acceleration mechanics: The major role of hamstrings in horizontal force production. *Frontiers in Physiology*, 6, 404. <https://doi.org/10.3389/fphys.2015.00404>
- Munteanu, G. Z., Munteanu, Z. V. I., Roiu, G., Daina, C. M., Moraru, R., Moraru, L., Trambitas, C., Badau, D., & Daina, L. G. (2021). Aspects of Tertiary Prevention in Patients with Primary Open Angle Glaucoma. *Journal of Personalized Medicine*, 11(9), 830. <https://doi.org/10.3390/jpm11090830>
- Opar, D. A., Piatkowski, T., Williams, M. D., & Shield A. J. (2013). A novel device using the Nordic hamstring exercise to assess eccentric knee flexor strength: a reliability and retrospective injury study. *The Journal of orthopaedic and sports physical therapy*, 43(9), 636-640. <https://doi.org/10.2519/jospt.2013.4837>
- Reeve, T. C., & Tyler, C.J. (2013). The validity of the SmartJump contact mat. *J Strength Cond Res.* 27(6), 1597-601. doi:10.1519/JSC.0b013e318269f7f1. PMID: 22843045.
- Sasaki, S., Koga, H., Krosshaug, T., Kaneko, S., & Fukubayashi, T. (2015). Biomechanical Analysis of Defensive Cutting Actions During Game Situations: Six Cases in Collegiate Soccer Competitions. *J Hum Kinet.* 46, 9–18. <https://doi.org/10.1515/hukin-2015-0029>
- Schache, A. G., Dorn, T. W., Williams, G. P., Brown, N. A., & Pandy, M. G. (2014). Lower-Limb Muscular Strategies for Increasing Running Speed. *J. Orthop. Sports Phys. Ther.* 44, 813–824. <https://doi.org/10.2519/jospt.2014.5433>
- Soyal, M., Aksoy Ömer, Şengöl, O., & Kılıç, S. (2023). Investigation of the relationship between isokinetic lower extremity strength and the vertical jump parameter in elite women football players. *Pedagogy of Physical Culture and Sports*, 27(3), 247-53. <https://doi.org/10.15561/26649837.2023.0309>
- Standing, R. J., & Maulder, P. S. (2017). The Biomechanics of Standing Start and Initial Acceleration: Reliability of the Key Determining Kinematics. *J Sports Sci Med.* 16, 154–162.
- Stølen, T., Chamari, K., Castagna, C., & Wisløff, U. (2005). Physiology of soccer: an update. *Sports Med.* 35, 501–536. <https://doi.org/10.2165/00007256-200535060-00004>
- Tupinambá Oliveira, M. C., Xavier de Souza, Áquila L., Mendonça, L. de M., & Ferreira da Silva, J. (2023). El ejercicio pliométrico mejora el rendimiento de los saltos en los atletas de voleibol: una descripción general de las revisiones sistemáticas (Does Plyometric Exercise Improve Jumping Performance in Volleyball Athletes. An Overview of Systematic Reviews). *Retos*, 50, 1188–1194. <https://doi.org/10.47197/retos.v50.96114>

- VALD Performance | Human Measurement Technologies. (2022). Retrieved 23 August 2022, from <https://valdperformance.com/>
- Van den Tillaar, R., Solheim, J. A. B., & Bencke, J. (2017). Comparison of hamstring muscle activation during high-speed running and various hamstring strengthening exercises. *Int J Sports Phys Ther.* 12(5), 718-727. PMID: 29181249;
- Vila Suarez, H., Khortabi, A., Rezavandzayeric, F. & Cancela Carral, J. M. (2023). Los efectos de un programa de entrenamiento de resistencia de alta intensidad y fuerza excéntrica en el rendimiento de jugadores de balonmano (The effects of a high intensity resistance and eccentric strength training program on the performance of handball players). *Retos*, 50, 1333–13339. <https://doi.org/10.47197/retos.v50.98948>
- Wallace, J. L., & Norton, K. I. (2014). Evolution of World Cup soccer final games 1966–2010: game structure, speed and play patterns. *J Sci Med Sport.* 17, 223–228. <https://doi.org/10.1016/j.jsams.2013.03.016>
- Wiemann, K., & Tidow, G. (1995). Relative activity of hip and knee extensors in sprinting - implications for training. *New Stud. Athlet.* 10, 29–49.
- Wirawan, O., Rusdiawan, A., Kusuma, D. A., Firmansyah, A., García-Jiménez, J. V., Zein, M. I., Pavlovic, R., Nowak, A. M., Susanto, N., & Pranoto, A. (2024). Los ejercicios unilaterales de fortalecimiento de los músculos isquiotibiales pueden mejorar la asimetría de los isquiotibiales y aumentar el rendimiento de salto en atletas de bádminton de sub-élite (Unilateral Hamstring Muscle Strengthening Exercises Can Improve Hamstring Asymmetry and Increase Jumping Performance in Sub-Elite Badminton Athletes). *Retos*, 54, 761–770. <https://doi.org/10.47197/retos.v54.103783>
- Wisløff, 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. *British journal of sports medicine*, 38(3), 285-288. <https://doi.org/10.1136/bjmsm.2002.002071>
- Yanci, J., & Camara, J. (2016). Bilateral and unilateral verticalground reaction forces and leg asymmetries in soccerplayers. *Biology of Sport*, 33(2), 179-183. <https://doi.org/10.5604/20831862.1198638>
- Zaharia, G., Badau, D., Tudor, V., Costache, R., Geambasu, A., Damian, M., Giurgiu, L., Damian, C., Ursu, V. E., Rusu, R.G., Hasmasan, I. T., Stoian, I., & Tifrea, C. (2023). The Effects of 8 Aerobic Endurance Training Weeks of 4vs.4+GK Small-Sided Games versus Traditional Training on Physical Fitness and Skills among U18 Football Players. *Applied Sciences*, 13(13), 7963. <https://doi.org/10.3390/app13137963>
- Zileli, R., & Söyler, M. (2021). The Examination of the Relationship between Sprint and Vertical Jump in Soccer Players. *MANAS Sosyal Araştırmalar Dergisi*, 10(1), 485–491. <https://doi.org/10.33206/mjss.726101>
- Sánchez-Sixto, A., & Floria, P. (2017). Efecto del entrenamiento combinado de fuerza y pliometría en variables biomecánicas del salto vertical en jugadoras de baloncesto Effects of combined plyometric and resistance training in biomechanical variables of the vertical jump in basketball players). *Retos*, 31, 114–117. <https://doi.org/10.47197/retos.v0i31.53340>

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