

## Sprint pattern analysis of professional female soccer players on artificial and natural turf Análisis del patrón de carrera en jugadoras de fútbol femenino en césped artificial y natural

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**Summary.** Introduction: There is few evidence that details the behavior of each spatiotemporal variable of the running pattern of female soccer players using different surfaces. Objective: To describe the spatiotemporal variables of the sprint pattern developed on natural and artificial turf by professional female soccer players. Methods: A cross-sectional study was conducted on nineteen (n=19) professional athletes with an average age of 22.3 years, who's sprint spatiotemporal variables were evaluated in a natural (Bermuda 419) and artificial (Star 2) playing field through an optical measurement system (Opto Gait, Italy). The analysis of the differences of the space and time variables by turf was done with the Wilcoxon test for paired data and the differences in speed and acceleration by playing position was done using the Kruskal-Wallis test. The Spearman test was used to compare the correlation between speed, acceleration and anthropometric variables. Finally, an alpha level of 5% was considered for the whole analysis. Results: On the natural turf, the speed and cadence of the players were higher; on the artificial turf, the energy, flight time, contact phase and step angle were higher (p<0.05). On the other hand, an indirect relationship was observed between speed, contact time, percentage and fat weight (p=0.01). Conclusion: Our results suggest that the natural turf, Bermuda 419, allows for a faster sprinting patterns, characterized by lower energy use, flight time, contact phase and step angle.

**Keywords:** Sprinting, speed meters, sports performance, athletes.

**Resumen.** Introducción: Existe poca evidencia que detalle el comportamiento de cada variable espaciotemporal del patrón de carrera de mujeres futbolistas utilizando diferentes superficies. Objetivo: describir las variables espacio temporales del patrón de carrera desarrollado en superficie natural y artificial por mujeres futbolistas profesionales. Métodos: se realizó un estudio de corte transversal en diecinueve (n=19) deportistas profesionales con un promedio de edad de 22.3 años, a quienes se les evaluaron las variables espacio temporales de la carrera en césped natural (Bermuda 419) y artificial (Star 2) a través de un sistema de medición óptico (Opto Gait). El análisis de las diferencias de las variables espacio temporales fue realizado con el test de Wilcoxon para datos pareados y las diferencias en la velocidad y aceleración fue realizados usando el test Kruskal-Wallis. El test de Spearman se usó para comparar la correlación entre las variables de velocidad, aceleración y antropométricas. Finalmente, un nivel de alpha de 5% fue considerado para el análisis total. Resultados: en la superficie natural, la velocidad y cadencia de las futbolistas fueron superiores; sobre superficie artificial, la energía, el tiempo de vuelo, la fase de contacto y el ángulo de paso fueron más altas (p<0.05). De otra parte, se observó una relación indirecta entre la velocidad, tiempo de contacto, porcentaje y peso graso (p=0.01). Conclusión: nuestros resultados sugieren que la superficie natural, Bermuda 419, permite un patrón de carrera más rápido, caracterizado por un menor uso de energía, tiempo de vuelo, fase de contacto y ángulo de paso.

**Palabras claves:** Carrera, medidores de velocidad, rendimiento deportivo, atletas.

### Background

Since its inception, soccer has retained the tradition of being played on natural turf so that most of the official matches of the International Soccer Federation (FIFA) are played on these types of surfaces. In the 1960s, thanks to technological progress and due to meteorological and economic factors influencing the conservation of natural turfs, the first artificial turf was created which, over time, has evolved to imitate the characteristics of its predecessor; however, its use has been a subject of discussion among soccer players (Gallardo, Felipe, Burillo, & Gallardo, 2010; Zanetti, Bignardi, Franceschini, & Audenino, 2013; Avalos, Gutierrez, Araya, Sánchez, Gutierrez, & Rojas, 2017).

The reviewed scientific literature mainly shows results of satisfaction levels in players and coaches, risk of injuries and ball behavior between different turfs. However, little research shows the differences between spatial-temporal or sports performance variables in natural and artificial turfs (Gallardo, Felipe, Burillo, & Gallardo, 2010; Williams, Akogyrem, & Williams, 2013; López et al., 2019). One of the

possible explanations is that there are no specific and objective measurement systems that allow to compare the influence that the types of turfs can have on the sprint pattern of soccer players. (Sánchez, García, & Felipe et al, 2016).

Some studies have already investigated the spatial-temporal differences of the sprint pattern by type of turfs and focus on speed and acceleration. The study by Gaudino et al. is an example. They showed that speed and acceleration are superior in natural and artificial grass when compared to the sand turf. Another study, that of Andersson et al. found no differences between movement patterns performed on artificial and natural turfs. For their part, Nédélec et al. and Gains et al. describe a higher running speed on artificial turf, compared to the natural one, a result which is in line with that observed by Choi et al. (Gaudino P, Gaudino C, Alberti G, & Minetti, 2013; Andersson, Ekblom, & Krstrup, 2008; Nédélec, McCall, Carling, et al, 2013; Gains, Swedenhjelm, Mayhew, Bird, & Houser, 2010; Choi S, Raymond K, Elean F, 2015).

Finally, this study was carried out considering the growing popularity of women's soccer, the scarce scientific evidence analyzing training processes and matches and, furthermore, the absence of studies determining the differences of spatiotemporal variables in the sprint pattern of female soccer players.

## Materials and Methods

A cross-sectional investigation was carried out in 19 players with an average age of  $22 \pm 4.6$  years, belonging to first division a Colombian professional club. Athletes agreed to participate voluntarily, with prior reading of informed consent or assent. An athlete was excluded because she did not complete the evaluation process ( $n=1$ ).

Among the variables analyzed are gender, age, height measured with (SECA 213, Germany) stadiometer, weight with (Tanita 679, Japan) scale; in addition, the folds of triceps, subscapular, ileo spinal, abdominal, anterior thigh and calf were taken, using a plicometer (Harpenden C-136, UK), with scale precision of 0.2 mm, in order to determine the percentage of body fat with Yuhasz's equation. Two bone breadths were measured from the following sites: femur, and wrist (bistylod). Rosscraft Campbell 10 anthropometers for small bones with a measurement range of 15 cm and accuracy to 0.1 cm were used (Rosscraft Innovations, Vancouver, Canada). Assessments were performed by 1 anthropometrist, whom had the International Society for the Advancement of Kinanthropometry (ISAK) certification at level 2. (Stewart AD, Marfell-Jones MJ, Olds T, de Ridder JH, 2011)

Likewise, the spatiotemporal variables measured were: contact phase, defined as the time from the first touch of the heel with the turf to the total support of the foot; resting phase, considered as the period in which the foot remains completely in contact with the ground; propulsion phase, which includes the time from the heel ascent to the lifting of the toe of the foot; stride, defined as the distance between the tips of the successive footprints of the same foot; cadence, understood as the rhythm expressed in steps per second; speed, taken as the relationship between the distance of the two feet and the sum of the first Contact Time ( $T_c$ ) with the Flight Time ( $T_f$ ); acceleration, which is the relationship between the delta of the speeds of the two steps and the sum of the contact and flight times; the height [cm], considered as the variation of the height of the center of gravity during the execution of the run; the step angle, defined as the angle of the tangent to the parabola generated by the movement of a stride and the energy, defined as the work necessary to accelerate a body of a given mass from rest to the indicated speed. (Optogait, 2018; Blazebich, 2011)

For the analysis of space and time variables, an optical measurement system (Optogait, Italy) was used, consisting of 5 transmitting and 5 receiving bars, 1-meter-long each, and 96 optical sensors that detect communication interruptions caused by the movement of the evaluated athlete. Thus, contact and flight times could be measured with a frequency of 1 KHz and with an accuracy of 1 cm. The literature reviewed shows an Intraclass Correlation Coefficient close to 1 for the Optogait measurement system in comparison to other devices that evaluate the space-time variables for the running pattern. (Lee, Song, Lee, Jung, Shin & Shin, 2014; Lienhard, Schneider & Maffiuletti, 2013).

## Procedure

Once the study subjects were socialized and the consents signed, the anthropometric assessment of weight, height, BMI, perimeters and folds was carried out. Subsequently,

the athletes were subjected to a 5-minute warm-up at a modified 3/10 Borg intensity, before making the maximum speed sprint pattern on the artificial turf of FIFA endorsed Star 2. The following day, the same procedure was carried out with previous warm-up on a 3 cm high homogeneous natural turf, Bermuda 419. The two evaluations were made in the same period of the day, to standardize the influences of circadian variations on the organism.

## Statistical Analysis

The data obtained was typed in Excel and exported to Stata 14.0 software for further analysis. Continuous variables were presented in median and interquartile ranges due to the small sample size and in means and standard deviation for purposes of comparison with other studies in the discussion. In addition, categorical variables were reported as absolute and relative values. The analysis of the

Table 1.  
General characteristics of the study population.

Variables	Mean/SD	Median/IQR	
Age (kg/mts <sup>2</sup> )	22 ± 4.6	23 (18-25)	
Size (mts)	151 ± 36	151 (155-161)	
Weight (kg)	57 ± 5.7	57.2 (51-61)	
BMI (kg/m <sup>2</sup> )	23 ± 2.0	23 (22-25)	
Fat (%)	18 ± 4.6	18 (13-21)	
Fat weight (kg)	11 ± 3.3	11 (7.4-13)	
Lean weight (Kg)	27 ± 1.9	27.3 (26-29)	
Bone weight (kg)	7.3 ± 0.9	7.3 (6.6-7.9)	
Residual weight (kg)	12 ± 1.1	12 (11-13)	
Variable	n=19	%	
Playing position	Defense	7	36.8
	Midfielder	9	47.3
	Forward	3	15.7

SD: Standard Deviation; IQR: Interquartile Range; BMI: Body Mass Index

Table 2.  
Spatio-temporal variables of the sprint pattern on natural and artificial surfaces.

Variable	Artificial Surface (n=19)		Natural Surface (n=19)		P
	Mean/SD	Median/IQR	Mean/SD	Median/RIC	
Specific energy (J/k)	0.13±0.04	0.12 (0.11-0.15)	0.07±0.05	0.06 (0.04-0.09)	<0.001
Total energy (J)	7.47±2.28	7.54 (6.40-9.37)	4.23±2.96	3.54 (2.16-5.31)	<0.001
Contact time (s)	0.17±0.01	0.17 (0.16-0.18)	0.17±0.01	0.18 (0.16-0.18)	NS
Flight time (s)	0.05±0.01	0.06 (0.05-0.06)	0.04±0.01	0.05 (0.03-0.05)	0.001
Height (cm)	0.44±0.15	0.40 (0.40-0.50)	0.29±0.16	0.30 (0.20-0.40)	<0.001
Speed (m/s)	5.39±0.15	5.38 (5.29-5.51)	5.63±0.33	5.71 (5.29-5.95)	=0.001
Acceleration (m/s <sup>2</sup> )	1.06±0.29	1.19 (0.89-1.30)	0.93±0.58	0.99 (0.70-1.26)	NS
Step (cm)	118 ± 29.0	123 (122-129)	1.26±8.68	125 (122-134)	NS
Stride (cm)	214±54.4	225 (208-244)	223±26.4	215 (201-253)	NS
Cadence(p/s)	4.29±0.25	4.24 (4.15-4.40)	4.46±0.27	4.42 (4.26-4.67)	<0.001
Step angle	0.80±0.27	0.77 (0.66-0.92)	0.55±0.28	0.56 (0.38-0.70)	<0.001
Contact phase(s)	0.02±0.02	0.015 (0.01-0.01)	0.01±0.00	0.013 (0.01-0.01)	NS
Contact phase (%)	8.77±2.22	8.4 (7-9.6)	7.93±1.96	7.30 (6.50-9.50)	NS
Supporting phase(s)	0.08±0.01	0.08 (0.07-0.09)	0.12±0.19	0.08 (0.06-0.09)	NS
Supporting phase (%)	50.1±5.94	51.2 (47-54.7)	46±12	46.8 (38.1-56.7)	NS
Propulsion phase(s)	0.07±0.01	0.06 (0.06-0.07)	0.08±0.02	0.08 (0.05-0.1)	NS
Propulsion phase (%)	40.9±5.96	41.1 (35.8-45.2)	45.9±12.0	42.2 (37.4-56.1)	NS

SD: Standard Deviation; IQR: Interquartile Range; J: joules; S: seconds; m: metres; p: steps; k: kilograms; NS: Not Significant.

Table 3.  
Speed and Acceleration by playing position.

Variable	Defense	Midfielder	Forward	p-value
Speed	5.68 (5.44-5.78)	5.53 (5.34-5.58)	5.47 (5.19-5.60)	NS
Acceleration	0.9 (0.66-1.12)	1.12 (0.80-1.32)	0.97 (0.65-1.21)	NS

NS: Not Significant.

Table 4.  
Correlation between anthropometric variables with speed and acceleration.

Speed	SN	S.A.	Acceleration	SN	S.A.
	Coefficient	Coefficient		Coefficient	Coefficient
BMI	-0.46	-0.41	BMI	-0.21	-0.35
%GC	-0.59*	-0.49*	%GC	-0.31	-0.43
Fat weight	-0.51*	-0.58*	Fat weight	0.29	-0.30
Lean weight	-0.23	-0.04	Lean weight	0.03	-0.08
Bone weight	0.37	0.34	Bone weight	0.03	0.29
Residual weight	-0.30	-0.40	Residual weight	-0.15	0.13

\*p < 0.05; SN: Natural Surface; SA: Artificial Surface; GC: Body Fat; BMI: Body Mass Index.

Table 5.  
Correlation between spatiotemporal variables of the sprint pattern.

Variable	Speed		Acceleration	
	SN	S.A.	SN	S.A.
Total Energy	0.26	0.003	0.14	0.65
Contact Time	-0.50*	-0.26	0.04	-0.03
Flight Time	0.18	0.01	-0.26	-0.14
Height	0.21	0.05	-0.27	-0.13
Pitch length	-0.25	-0.05	-0.07	-0.11
Stride	-0.19	-0.02	-0.20	-0.20
Cadence	0.42*	0.39	0.23	0.29
Step angle	0.15	-0.04	-0.36	-0.10
Contact Phase	0.12	-0.21	-0.45	0.26
Support phase	-0.35	0.05	0.22	-0.33
Propulsion phase	-0.32	-0.37	-0.16	0.08

Significant Correlation \* < 0.05; SN: Natural Surface; SA: Artificial Surface

differences of the space and time variables by turf was done with the Wilcoxon test for paired data and the differences in speed and acceleration by playing position was done using the Kruskal–Wallis test. The Spearman test was used to compare the correlation between speed, acceleration and anthropometric variables. Finally, an alpha level of 5% was considered for the whole analysis.

## Results

Table 1 shows the following medians: age 23 years; height 1.51 m; weight 46 kg; Body Mass Index (BMI) 19.2 kg/m<sup>2</sup>; fat weight 11 kg; lean weight 27.4 kg; bone weight 7.3 kg; and residual weight 12 kg. Most of the players evaluated were midfielders, followed by defenders and strikers.

Table 2 shows that the speed and cadence of the players were superior in natural turf (<0.001). Energy, flight time, contact phase and step angle were found to be higher on artificial turf (<0.001).

Table 3, indicates that the defenses have the highest median speed and that midfielders have the best acceleration; however, the differences between these two variables by playing position are not statistically significant.

Table 4 shows a moderate indirect relationship between speed, percentage and fat weight on both turfs ( $p=0.01$ ).

Table 5 shows a moderate indirect relationship between speed and contact time and a direct relationship between speed and cadence on natural turf ( $p<0.05$ ).

## Discussion

The results found suggest that the natural turf Bermuda 419 allows a faster running pattern, characterized by lower energy use, flight time, contact phase and step angle. As for speed and acceleration, the literature found shows that distances travelled at high speeds have a direct relationship with success in the game. (FIFA, 2011; FIFA, 2015).

In our study, the median speed developed on the natural turf was 5.63 m.s or 20.2 km. h. After the performance analysis of the teams participating in the last two female World Cups 2011 and 2015, these speeds are considered by FIFA as a high-speed sprint or optimal sprint and constitute between 0.5% and 5% of the total playing time and between 1% and 12% of the total average distance covered by a soccer player. (FIFA, 2011; FIFA, 2015; Rienzi, Drust, Reilly, Carter, & Martin, 2000; Van Gool D, van Gerven D, Boutmans, 1988). The importance of speed lies mainly in the fact that it develops around the ball, through the processes of unmarking with possession of the ball or during defensive reconstruction without the ball. These aspects have been considered as the main determinants of success in the game when compared with the total distance traveled in other types of actions at other speeds. All of the above indicates that, in addition to the technical and tactical elements, running at higher speeds with greater regularity is also determinant for success in the game. (Andrzejewski, Chmura, Pluta, et al, 2013; Reilly, Bangsbo, & Franks, 2000; Jastrzebski, Bichowska, Rompa, Radziminski, & Dargiewicz, 2014; Sánchez, Hernández, Muñoz, Gonzales, Fernández & Carretero, 2016).

The differences in speed by type of turf shown in this

study present some discrepancies with those obtained in other investigations, where speeds are higher when developed on artificial turf (Nédélec, McCall, Carling, et al, 2013; Gains, Swedenhjelm, Mayhew, Bird, & Houser, 2010; Choi S, Raymond K, Elean F, 2015). According to Nédélec M. et al., this type of turf presents better conditions for speed races, due to greater friction and impact absorption. However, other studies state that there is no difference in the speed or acceleration developed between the two types of turfs, as long as the natural grass is in an optimum state. (Reilly, Bangsbo, & Franks, 2000; Jastrzebski, Bichowska, Rompa, Radziminski, & Dargiewicz, 2014; Ten, Burillo, 2012).

The natural grass used (Bermuda 419 or *Cynodon dactylon* x *Cynodon transvaalensis*) is characterized by being very dense, homogeneous, thin-leaf, highly resistant to intense traffic and to temperate climates similar to that of the place where the tests were carried out. It is necessary to emphasize that at the time of the evaluations, the natural grass had only one year of use, contrary to the 7 years of the Star 2 turf with which it was compared. This condition can vary the characteristics of the game, among them the speed, which was lower in artificial turf. (Gallardo, Felipe, Burillo, & Gallardo, 2010)

On the other hand, no statistically significant differences were observed when analyzing the speed by playing position. The literature found shows that the lateral midfielders, the lateral defenders and the strikers are the positions that travel the greatest distance at intensive acceleration speed (18-21 km/h), which was reached by most of the players evaluated. (FIFA, 2011; FIFA, 2015)

Another variable studied was flight time, which was shown to be higher in artificial grass  $p<0.05$ . This variable, as well as the other spatial-temporal variables, usually changes with the increase in speed. Novacheck argues that higher speeds are related to a longer flight phase and a shorter contact time; however, in our study, the sprint pattern evaluated on natural turf showed a shorter flight time despite presenting higher speed values, contrary to Novacheck's claim. (Novacheck, 1998).

On the other hand, Vanderka, Kampmiller, 2013; Seagrave, Mouchbahani, O'donnell, 2009; and Mackala K, 2007, consider that the most important criteria for the selection of young runners are stride length, contact time and cadence. In the population studied, these last two criteria could have been the determining factors for reaching higher speeds on natural turf; the above could be justified by the findings of higher cadence on natural turf, as well as the direct relationship found between speed and cadence ( $r$ ): 0.42;  $p<0.05$ ), and the negative relationship between contact time and speed ( $r$ : -0.57;  $p<0.05$ ).

The step angle generated by the stride is another variable that showed statistically significant differences. Alcaraz, Palao, Elvira, & Linthorne, 2008; Santos, Tam, Granados, et al, 1889 refer that this variable has a direct relationship with sprint economy; in contrast, our study shows that, in natural grass, the step angle was lower, as was the use of energy. This low energy expenditure can be explained by the lesser variation of the center of gravity when the running pattern was developed over a natural turf. (Tartaruga, Brisswalter, Peyré-Tartaruga, Avila, Alberton, Coertjens, Cadore,

Tiggemann, Silva, Krueel, 2012).

The indirect relationship between the BMI and fat percentage with the speed developed by the soccer players evaluated coincides with the data referred by the reviewed literature, which indicates that an increase in the percentage of body fat may decrease aerobic and anaerobic performance. (Collins, Silberlicht, Perzinski, Smith, & Davidson, 2014). As far as morphological characteristics are concerned, the investigations found show that female soccer players have a height between 160cm and 169cm, a weight between 52kg and 65kg and a fat percentage between 16% and 23%. When comparing these results with those obtained in the present study, height was the only variable outside the range already described. In this regard, it is important to note that anthropometric characteristics vary according to the particular needs of the sport, the role of the athlete in the playing field, sprint and of course gender. (Milanoviæ, Sporiš, James, Trajkoviæ, Ignjatoviæ, Sarmiento, Trecroci, & Mendes, 2017).

Finally, despite the differences shown in the sprint pattern by type of grass, it is possible to highlight some variables that cannot be controlled, such as the type of boot, the sleep pattern and the diet before the evaluations. Additionally, it is important to note that soccer players often start their sprints from a pre-motion and non-stationary condition as performed in this study. The conditions mentioned above can be considered limitations that influence the results of the career pattern and that must be taken into account for subsequent studies.

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### Ethics Approval and Consent to Participate

All procedures followed conform to the ethical standards of the responsible human committee and in accordance with the World Medical Association and the Declaration of Helsinki. This study was approved by the research committees of the Faculty of Physical Culture Sport and Recreation of the University of Santo Tomas-Bucaramanga and of the Physiotherapy Program of the University of Santander-Bucaramanga (interinstitutional agreement code B-293). The ethical principles of confidentiality, beneficence, non-maleficence, autonomy and justice were respected. The authors have obtained the informed consent of the participants referred to in the article.

### Competing Interests

The authors, declare that they have no competing interests.

### Bibliography

- Alcaraz PE, Palao JM, Elvira JL, Linthorne NP. (2008) Effects of three types of resisted sprint training devices on the kinematics of sprinting at maximum velocity. *Journal of Strength & Conditioning Research*. 22(3), 890-897.
- Andersson H., Ekblom B., Krstrup P. (2008) Elite soccer on artificial turf versus natural grass: Movement patterns, technical standards, and player impressions. *J. Sports Sci.*; 26:113–122.
- Andrzejewski M, Chmura J, Pluta B, et al. (2013) Analysis of sprinting activities of professional soccer players. *J Strength Cond Res*; 27:2134–40.
- Avalos J, Gutierrez R, Araya G, Sánchez B, Gutierrez JC, Rojas D. (2017) Effects of artificial turf and natural grass on physical and technical performance of professional soccer players. *Revista del MHSalud*; 14(1): 1-19.
- Blazevich, A. (2011). *Biomecánica deportiva*. Boldalona: Paidotribo.
- Choi S, Raymond K, Elean F. (2015) Comparison between Natural Turf and Artificial Turf on Agility Performance of Rugby Union Players. *Advances in Physical Education*. 5:273-281.
- Collins SM, Silberlicht M, Perzinski C, Smith SP, Davidson PW. (2014) The relationship between body composition and preseason performance tests of collegiate male lacrosse players. *J Strength Cond Res*. 28(9):2673–9.
- FIFA. (2011). *Analysis of physical performance during the FIFA Women's World Cup 2011 Zurich*. Available at: <https://resources.fifa.com/image/upload/physical-analysis-germany-2011-1680699.pdf?cloudid=cs9yovdnq1mk4fvj4g2s>
- FIFA (2015). *Analysis of physical performance during the FIFA Women's World Cup 2015. Zurich Switzerland*. Available at: <https://img.fifa.com/image/upload/zbgh1drt57dhsqg72auv.pdf>
- Gains GL, Swedenhjelm AN, Mayhew JL, Bird HM, Houser JJ. (2010) Comparison of speed and agility performance of college soccer players on field turf and natural grass. *J Strength Cond Res*. 2010; 24:2613–2617.
- Gallardo A, Felipe JL, Burillo P, Gallardo L. (2010) Satisfaction of coaches and sportsmen with the soccer fields. *Culture, Science and Sport Magazine*. 5: 189-199.
- Gallardo, A, Felipe, JL, Burillo, P, Gallardo, L. (2010) Trainers and players satisfaction in the grass and artificial turf football fields. *Cult cienc deporte* 15: 189-199.
- Gaudino P, Gaudino C, Alberti G, Minetti AE. (2013) Biomechanics and predicted energetics of sprinting on sand: hints for soccer training. *J Sci Med Sport*. ;16(3):271–5.
- Jastrzebski, Z, Bichowska, M., Rompa, P, Radziminski, L, Dargiewicz R. (2014) Influence of different types of surfaces on the results of running speed tests in young soccer players. *Central European Journal of Sport Sciences and Medicine*. 1(5): 5-14.
- López-Gómez, B., Pérez-Mendoza, D., Guzmán-Revelo, J., Rangel-Caballero, L., Corzo-Vargas, Y., de Paula Facioli, T., Angarita Fonseca, A., & Sanchez Delgado, J. (2020). Análisis del patrón de carrera sobre superficie artificial y natural en futbolistas adolescentes (Analysis of the running pattern on artificial and natural surface in

- adolescent football players). *Retos*, 38(38), 109-113.
- Mackala K. (2007) Optimisation of performance through kinematic analysis of the different phases of the 100 meters. *New Studies in Athletics*.;22(2):7-16.
- Microgait. (s.f.) *Optogait user manual*. Version 1.11.1. Italy. Available at: <http://www.optogait.com/OptoGaitPortal/Media/Manuals/Manual-ES.PDF> (Access 8 Jul 2018).
- Milanovič Z, Sporiš G, James N, Trajkovič N, Ignjatovič A, Sarmiento H, Trecroci A, (2017) Mendes BMB. *J Hum Kinet.*; 28 (60):77-83.
- Nédélec M, McCall A, Carling C, et al. (2013) Physical performance and subjective ratings after a soccer-specific exercise simulation: comparison of natural grass versus artificial turf. *J Sports Sci Med.*; 31:529-536.
- Novacheck, TF. (1998) The biomechanics of running. *Gait & posture* 7(1): 77-95.
- Núñez, F. J., Toscano-Bendala, F. J., Suarez-Arrones, L., Martínez-Cabrera, F. I., & De Hoyo, M. (2018). Individualized thresholds to analyze acceleration demands in soccer players using GPS (Umbral individualizados para analizar las demandas en la aceleración en futbolistas usando GPS). *Retos*, (35), 75-79.
- Reilly T, Bangsbo J, Franks A. (2000) Anthropometric and physiological predispositions for elite soccer. *J Sports Sci.*; 18:669-683.
- Rienzi E., Drust B, Reilly T, Carter JE., Martin A. (2000) Investigation of anthropometric and work-rate profiles of elite South American international soccer players. *J Sports Med Phys Fitness*; 40(2):162-9.
- Sánchez J, García J, Felipe JL et al. (2016) Physical and physiological responses of amateur soccer players on third generation artificial turf systems during simulated game situations. *J Strength Cond Res.*; 30(11): 3165-3177.
- Sánchez Sánchez, J., Hernández Familiar, C., Marcos Muñoz, V., González García, A., Rodríguez Fernández, A., & Carretero González, M. (2016). Mejora de la capacidad para repetir sprints en jóvenes futbolistas: entrenamiento intermitente de alta intensidad con y sin cambios de dirección (Effect of intermittent training with and without direction changes on the physical performance of young player). *Retos*, (30), 70-75.
- Santos, J, Tam, N, Granados, C, et al. (2014) Stride angle as a novel indicator of running economy in well-trained runners. *J Strength Cond Res* 36: 1889-95.
- Seagrave L, Mouchbahani, R, O'donnell K. (2009) Neurobiomechanics of maximum velocity sprinting. *New Studies in Athletics*; 24(1), 19-29.
- Stewart AD, Marfell-Jones MJ, Olds T, de Ridder JH. (2011). International standards for anthropometric assessment. *ISAK, Lower Hutt*
- Tartaruga MP, Brisswalter J, Peyré-Tartaruga LA, Avila AO, Alberton CL, Coertjens M, Cadore EL, Tiggemann CL, Silva EM, Kruel LF. (2012) The relationship between running economy and biomechanical variables in distance runners. *Res Q Exerc Sport*; 83:367-375.
- Ten O, Burillo P. (2012) Influence of the playing surface on the performance of amateur soccerers: natural grass, artificial turf and soil. *AGON International Journal of Sport Sciences.*; 2(2): 106-114.
- Vanderka M, Kampmiller T. (2013) Kinematics of Sprinting in Children and Youths. *New Studies in Athletics.*; 28: 35-45.
- Van Gool D, van Gerven D, Boutmans J. (1988) The physiological load imposed on soccer players during real match-play. In: Science and Soccer Committee. *World Congress of Science and Soccer. Liverpool*, 52-9.
- Williams JH, Akogyrem E, Williams JR. A (2013) Meta-Analysis of Soccer Injuries on Artificial Turf and Natural Grass. *J Sports Med*. 1-6.
- Zanetti EM, Bignardi C, Franceschini G, Audenino AL. (2013) Amateur soccer pitches: mechanical properties of the natural ground and of different artificial turf infills and their biomechanical implications. *J Sports Sci.*; 31(7):767-78.

