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ORIGINAL

PLANTAR DYNAMICS IN BALANCE, POWER, SPEED, AND TENNIS SERVICE TESTS

DINAMICA PLANTAR EN PRUEBAS DE BALANCE, POTENCIA, VELOCIDAD, Y SERVICIO EN TENISTAS

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ABSTRACT

The objective of this report is to describe the plantar dynamics during the tennis serve and during specific tests of power, speed, and balance in tennis players and to establish their relationships. A descriptive method was established in which 16 athletes were evaluated by tests of performing power, speed, balance, and top spin serving. Descriptive measures were made for the results of these tests and those of the plantar dynamics and were correlated with each other. The results suggest that the center of anteroposterior pressure of the foot (COP-AP) during the balance tests had an average of -32 mm; in turn, the average power during the jump in the serve was 165 ±35 N. A relationship (r = 0.45) was found between the time in the air and the centimeters jumped, along with a relationship between the time of the speed test and the time of the running cycle (r = 0.54).

KEYWORDS: Plantar Dynamics, balance, power, speed, tennis, physiotherapy.

RESUMEN

El objetivo del presente reporte es describir la dinámica plantar durante el servicio y durante la realización de pruebas específicas de potencia, velocidad y equilibrio en tenistas y establecer su relación. Se estableció un método descriptivo, se evaluaron a 16 deportistas realizando pruebas de potencia, velocidad, equilibrio y servicios tipo top spin, se realizaron medidas descriptivas para los resultados de las pruebas y los de la dinámica plantar, y se correlacionaron entre sí. Los resultados sugieren que el centro de presión anteroposterior del pie (COP-AP) durante las pruebas de equilibrio tuvieron un promedio de -32mm, a su vez, el promedio de potencia durante el salto en el servicio fue de 165 ±35 N. Se encontró una relación (r=0,45) entre el tiempo en el aire y los centímetros saltados, además entre el tiempo de la prueba de velocidad y el tiempo del ciclo de la carrera (r=0,54).

PALABRAS CLAVE: Dinámica plantar, balance, potencia, velocidad, tenis, fisioterapia.

INTRODUCTION

The fundamental technique of tennis is based on a driving pattern of striking, in which the collision of two moving objects (racket and ball) with different morphological and mechanical characteristics occurs, where adaptations related to the amount of force, speed and direction of the ball, and trajectory to the different situations of the game are put into play. These game situations are actions that are executed at high speed and in a short amount of time (1).

One of the determinants of performance in tennis is the execution of the serve, which must be as fast and precise as possible because it is the only movement in which the player has total control over the synchronization, speed, direction, and rotation of the ball, without any influence from their opponent. It is also one of the most complex movement gestures in sports and requires years of practice to perform effectively during a competition; for this reason, it has been the subject of research (2).

The tennis serve technique in particular has received more attention in the literature than the other strokes, likely because it is the easiest stroke to study, since it starts from a fixed position and the player has total control. The main objective focuses on the projection of the ball with the greatest possible speed and in the right direction to obtain the point. The serve includes a sum of forces largely sequenced proximally to distal (feet, legs, trunk, arm/racket), which requires a sequence of coordinated movements with the appropriate rhythm of each segment (3) (4).

Differences within the biomechanics of the serve that could be key to serve analysis have been observed in elite athletes (5), who, due to years of dedication, have improved their corporal mechanics, optimizing their performance on the field. According to the literature, electromyograms of the lower extremities have shown profiles of the reaction force of the ground that characterize the tennis serve, finding that the serves of elite players are different from those of lower-level players by their patterns of more refined neuromuscular coordination (6).

These patterns of neuromuscular coordination are reflected by using the body in a fluid and integral way, contributing to improve the power of the blow. A good stroke starts at the feet, flows through the knees and legs, uses the hip, depends in part on the body weight, and allows the upper body to impact the ball; all of the above depend on the work of kinetic chains. A good serve starts in the base of support, since the transmission of loads occurs synchronously through the muscular chains that facilitate the production of the gesture, taking into account from the base of support variables, such as the pressure force of the foot, the power and center of mass during the serve that can generate greater understanding of the technical gesture (7).

Among other skills necessary for the sport of tennis, this article will explore balance, speed, and power, with the objective of describing the plantar dynamics during the serve and during the performance of specific tests of power, speed, and balance and correlating them with each other.

MATERIALS AND METHODS

This descriptive study was conducted with 16 male tennis players with an average age of 18 (±2.8) years and an average time of playing sports of 7.9 (±4.3) years, belonging to two national tennis teams in Bogota. We excluded tennis players who had presented some type of injury in the past month or who had active symptoms of localized pain in the shoulder, pinching or tendonitis of the rotator cuff, or pain radiating from the spine or the lower limbs. The measurements were taken after guaranteeing that the athletes had not competed in the last 48 hours. All participants signed an informed consent form after being made aware of the minimum risk of the investigation.

Instruments

Balance, power, and speed tests were performed in addition to the serve test. For the evaluation of balance, the "y" test was used (8). This test is a reliable test that allows demonstrating functional symmetry. The test is performed while balancing on one leg and reaching as far as possible with the contralateral leg in three different directions. The three directions of movement are anterior, posteromedial, and posterolateral, performed for each leg. Therefore, there are six tests to be performed, in the following order: right anterior reach, left anterior reach, right posteromedial reach, left posteromedial reach, right posterolateral reach, and left posterolateral reach. Each of the reaches was measured in centimeters.

To evaluate the power, the vertical jump test was performed with legs together, with the following procedure: first, the height marker was made by the participant, who was facing a wall with their feet fully supported and together, the trunk straight and the arms extended above the head at shoulder-width, the hands open and with the palms resting on the wall. Using wetted fingers, they indicated their maximum height attainable. Then, the jump was performed with the participant positioned laterally next to the wall, approximately 20 cm away, with their trunk straight, arms down along the body and legs extended, with their feet parallel to the wall approximately shoulder-width apart; at the signal, the performer could tilt their body, flex their legs several times (without taking their feet off the ground), and swing their arms to make an explosive movement of jumping up. During the flight phase, the trunk and arm closest to the wall should be extended as far as possible, marking the highest possible height with the middle finger. The number of centimeters that existed between the two marks made by the subject was measured. Jumps that had a twist of the trunk were considered invalid. Three attempts were made, and the best was used for analysis (9).

For the evaluation of the speed, the 30-m Sprint Test was performed. Initially, the athlete was placed in a high starting position, behind a line 15 m before the timing line. At the signal of the examiner, the athlete began to run as fast as possible to reach their maximum speed when reaching the timed 30 m (marked with flags). The time spent in the last 30 m was timed. The timekeeper stood at the finish line and activated the timer at the signal of a second timekeeper situated at the start of the 30 m, who lowered his arm quickly at the moment the runner passed (9). The results were recorded in seconds.

For the evaluation of the serve, a video recording of the player was used after the alternation of serves to the zone demarcated by each player (a complete basket) (10). The type of floor on which the serves were performed was brick dust. There were five top spin serves, the best of which was analyzed.

For the evaluation of the plantar dynamics, the electronic templates OpenGo MOTICON ® (11) were used during all tests; using 13 sensors, the center of pressure was measured in millimeters (mm) (COP), the power was measured in Newtons per second (N/s), and the reaction force of the foot was measured in Newtons (N) during each activity. The sampling frequency used was 100 Hz. To understand the plantar dynamics in tennis players, some variables were analyzed based on the tests applied.

During the "y" test, the COP mm was analyzed in the anteroposterior (AP) and mediolateral (ML) planes of the foot, as was the COP velocity in mm/ms during the six positions. During the power test, the average time in the air determined by the sensors of the templates was taken into account. In the speed test, the run cycle time was analyzed, with the analyzed variables of the plantar dynamics during the serve consisting of the average time in the air during the jump performed in this serve (top spin effect). In addition, the power of the jump in N/s, the plantar pressure in N/cm^2 during the takeoff of the jump and during the landing, and the reaction forces in N of the right and left leg were analyzed.

Process

After the signing of the informed consent form, an overall and specific warm-up was given. The templates were then positioned, calibrating the pressure of zero in each player, followed by the tests of balance, power, and speed, and in the end, the serving-specific warm-up was performed (one basket) to finish with the recording of the last five serves. The templates were removed, and the data for each player were downloaded for filtering and analysis.

Analysis

All data were recorded in Microsoft® Excel. Descriptive measurements of averages and standard deviations were made, and Spearman correlation measurements were established between the results of the physical tests and the plantar dynamics measured with the OpenGo MOTICON ® templates.

RESULTS

The evaluated participants had an average body mass index of 21.5 ±3.4. Within the tests performed (Table 1.), the average centimeters jumped was 47.6 ±6.2 cm, the average time to run the 30 meters was 3.8 sec, and the centimeters reached in the "y" test with the leg contralateral to the support were close for both lower limbs.

Table 1. Descriptive Physical Tests

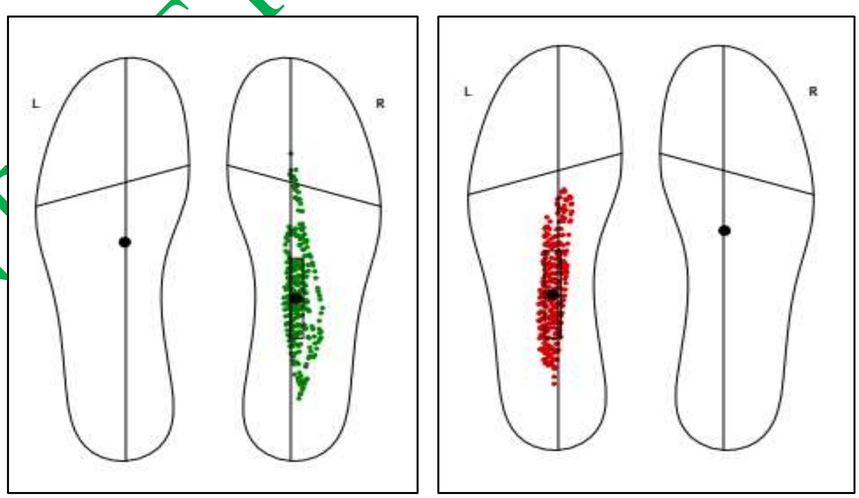
PHYSICAL TEST	AVERAGE	SD
BALANCE RLL (cm)		
ANTERIOR RIGHT	60.8	6.37
POSTERIOR RIGHT	94.8	12.5
POSTERIOR LEFT	85.8	11.0
BALANCE LLL (cm)		
ANTERIOR RIGHT	63.5	5.8
POSTERIOR RIGHT	94.8	12.5
POSTERIOR LEFT	86.7	11.6
VERTICAL JUMP (cm)	47.6	6.2
SPEED (s)	3.8	0.5

RLL: Right lower limb
LLL: Left lower limb

With respect to the plantar dynamics during the equilibrium test, it was evident that the COP AP moved more posteriorly in the right foot than in the left foot; in turn, the COP speed was higher in the left leg (Table 2.).

In Figure 1, the behavior of the pressure center of one of the athletes in a Cartesian plane is observed. The right foot (green color) and the left foot (red color) represent the support foot in the Y test, and the zone marked with color indicates the displacement of the center of pressure in the AP direction on the Y axis; it can be observed that the behavior was similar in both feet.

Fig. 1. Displacement of the center of pressure in the "Y" test



Regarding the jump, the average air time was 0.57 seconds, and the jump power was 165 N. Pressure was higher at the time of landing, and the reaction force on the ground was always greater in the left leg (Table 2).

Table 2. Descriptions of the Plantar Dynamics in Each Test

BALANCE (Y TEST)	**RIGHT**	**LEFT**
COP AM (mm)	-32.5 (31.7)	-11.35 (26.4)
COP ML (mm)	-0.29 (1.7)	0.41 (2.9)
VELOCITY COP mm/ms	235.9 (92.8)	247.5 (71.1)
VERTICAL JUMP		
TIME IN THE AIR (s)	0.53 (0.15)	
SPEED (30-m Sprint)		
TIME OF THE RUN CYCLE	0.52 (0.26)	
SERVE		
TIME IN THE AIR (s)	0.57 (0.28)	
JUMP POWER (N/s)	165 (35)	
PRESSURE DURING THE TAKE-OFF (N/cm^2)	41 (1.4)	52.6 (2.0)
PRESSURE DURING LANDING (N/cm^2)	69.4 (2.4)	65.1(2.8)
FORCE OF REACTION IN THE GROUND (N)	114(20.5)	122(21.8)

When establishing the correlation between the results of the plantar dynamics obtained through the OpenGo software and those given by each of the tests, a moderate relationship was found between the displacement of the COP ML and the posterior reach of the left leg when evaluating the equilibrium of the right leg ($p < 0.05$). A relationship was also found between the speed of the COP and the centimeters of posterior reach of the same leg (Table 3).

Table 3. Correlation Indexes between plantar dynamics and physical tests

PHYSICAL TEST	COP AP (mm)	COP ML (mm)	SPEED COP mm/ms
BALANCE RLL (cm)			
ANTERIOR RIGHT	-0.137608405	0.381667806*	0.077952671
POSTERIOR RIGHT	0.167775502	-0.205998346	0.259409963
POSTERIOR LEFT	0.104870279	-0.224225519	0.396900244*
BALANCE LLL (cm)			
ANTERIOR RIGHT	-0.006555578	-0.138853951	-0.089117244
POSTERIOR RIGHT	-0.137172303	-0.203107556	0.077510609
POSTERIOR LEFT	-0.222391818	-0.1841351	0.29023066
VERTICAL JUMP (cm)	**TIME IN THE AIR**		
	0.452012858*		
SPEED (s)	**TIME OF THE RUN CYCLE**		
	0.525994415*		
	TIME OF DOUBLE SUPPORT		
	0.029120034		

A relationship between the time in the air during the vertical jump and the centimeters reached in the test was also found. Finally, a relationship was found between the seconds of the 30-m sprint test and the time of the run cycle reported in the software.

DISCUSSION

The findings from an analysis of the variables of plantar pressure, power, and COP in tennis players during selected movements related to the sport of tennis, including jumps, speed, and balance, show that the COP tends to be more posterior in the right leg and that its speed is lower in the lower limbs; thus, a more posterior COP can be related to greater balance in the applied test and less displacement of the COP. In addition, the plantar pressure was greater during the landing than during the takeoff and in the lower limb, where the greatest force of pressure was generated in the left leg.

Taking the above findings into account, investigations in which plantar pressure has been defined as a variable in relation to the dominant foot in other athletic sports such as football have shown that the distribution of plantar pressures in the participants is homogeneous in both feet in a gesture that implies multiple activations of muscular chains; this distribution has been analyzed with tools such as the EMED Pedar templates from the Novel company and the Footscan template system (12)(13). However, the templates described above only measure the plantar pressure (14), while the OpenGo Physio templates used in the current work allow simultaneous, accurate, and wireless measurements of the distribution of plantar pressures, total loads, and trajectory of the center of gravity (11).

It is important to note that the plantar pressures are influenced by the interaction of the athlete with the environment in terms of specific sports shoes, the type of movement, the momentum, and/or the nature of the ground surface (court), which can modify the ways in which the load is distributed and the center of mass is displaced(3). These variables make it difficult to directly compare plantar pressures with other studies, such as those developed with the EMED Pedar and Footscan templates, where the analysis of these pressures was conducted in a controlled environment; as they are not wireless, testing in other field settings was not possible (12)(13). However, the OpenGo Physio templates allow the collection of data variables on both brick dust and hard court surfaces, which are specific to the game of tennis, as was the case with this work. (16)

Other studies, such as the one by Girard (17), analyzed plantar pressures during the tennis serve with the use of electromyography techniques and concluded that 80% of the total load of the front foot was concentrated in the hallux, the toes, and the forefoot, which suggests that the anterior area of the front foot can contribute significantly to good performance in the serve; meanwhile, in the back foot, the relative loads are distributed through the foot in a similar way and with less variability. This finding agrees with the results obtained in the present work, where it was evidenced that the displacements of the centers of mass of the participants in both groups were greater towards the anterior part of the foot than towards the posterior part in the jump phase during the serve, with positive values in the analysis obtained with the use of OpenGo Physio templates.

It will be necessary to conduct investigations with a larger sample size that allow an understanding of the behavior of pressure forces during the serve, along with a better understanding of the overall plantar dynamics in tennis.

CONCLUSIONS

During the top spin-type serve, greater pressure force was found in the landing phase. In the takeoff phase, the left foot received the greatest load. In contrast, during the landing, the right foot received the greatest pressure per square centimeter.

REFERENCES

1. Frutos JB. Análisis estructural del golpeo en tenis: una aproximación desde la biomecánica. Eur J Hum Mov. 2013;(31):111–33.
2. Infantes TU, Davó HH, Hernández FJM. Variabilidad cinemática en relación con el rendimiento en el saque en jóvenes tenistas. Eur J Hum Mov.

2012;(29):49–60.
3. Izquierdo M, Redín M. Biomecánica y bases neuromusculares de la actividad física y el deporte. Madrid: Ed. Médica Panamericana; 2008. 796 p.
4. Gómez M, Zissu M. Evaluación biomecánica del saque de tenis de campo ejecutado por atletas participantes en el Torneo Internacional Future. Dir Aula Competencia Med y Ciencias Apl. 2006;22.
5. Menayo R, García JPF, Hernández FJM, Clemente R, Calvo TG. Relación entre la velocidad de la pelota y la precisión en el servicio plano en tenis en jugadores de perfeccionamiento. Eur J Hum Mov. 2008;(21):17–30.
6. Ellenbecker TS, Roetert EP, Reid M. Biomecánica del Saque de Tenis: Consecuencias para el Entrenamiento de Fuerza. Strength and Conditioning Journal. 2009; 31 (4):35-40
7. Abrams GD, Harris AH, Andriacchi TP, Safran MR. Biomechanical analysis of three tennis serve types using a markerless system. Br J Sports Med. 2014 Feb;48(4):339–42.
8. Shaffer SW, Teyhen DS, Lorenson CL, Warren RL, Koreerat CM, Straseske CA, et al. Y-Balance Test: A Reliability Study Involving Multiple Raters. Mil Med. 2013 Nov;178(11):1264–70.
9. López E. Pruebas de aptitud física. Barcelona: Editorial Paidotribo; 2002. 370 p.
10. Álvarez J. Calentamiento y vuelta a la calma en el tenis. Revista digital Editorial Universitas MH; 2011. Disponible en https://www.yumpu.com/es/document/view/14367978/alonso-j-esp-calentamiento-y-vuelta-a-la-calma-en-el-tenis-itf.
11. Stöggl T, Martiner A. Validation of Moticon's OpenGo sensor insoles during gait, jumps, balance and cross-country skiing specific imitation movements. J Sports Sci. 2017;35(2):196–206.
12. Zafra P, Berna J. Análisis de la presión plantar entre el pie dominante y no dominante en jugadores de fútbol profesional. *THERAPEIA* 6. 2014: 45-57
13. Hong Y, Wang L, Li JX, Zhou JH. Comparison of plantar loads during treadmill and overground running. J Sci Med Sport. 2012 Nov;15(6):554–60.
14. García F. Reflexiones en Torno al Movimiento Corporal Humano desde una Perspectiva Multidimensional y Compleja. Ciencias e innovación en salud. 2013; 1(1):78-91
15. Natali AN, Forestiero A, Carniel EL, Pavan PG, Dal Zovo C. Investigation of foot plantar pressure: experimental and numerical analysis. Med Biol Eng Comput. 2010 Dec;48(12):1167–74.
16. Girard O, Eicher F, Micallef J-P, Millet G. Plantar pressures in the tennis serve. J Sports Sci. 2010; 28(8):873–80.

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