Palestrica of the third millennium – Civilization and Sport
Vol. 16, no. 4, October-December 2015, 333–337

Research approach for outlining the biomechanical parameters of the tennis serve
Demersuri de cercetare pentru obiectivizarea parametrilor biomecanici ai serviciului în tenis

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Abstract

Background. In tennis, every technical procedure is influenced by the player's technique. In order to develop a correct technical procedure for a particular type of player with aspirations of becoming a professional, we must take into account the stroke mechanics of every movement, depending on the physical features of the player in question.

*Aims.*The comparative analysis of certain methods for the identification of biomechanical parameters of tennis serves.

Methods. In order to solve the problem related to the technical value and particularities of the tennis serve, a video recording and the DARTFISH analysis program was used as the equipment, together with the methodology of acquisition of kinematic data, developed by Xsens, Moven.

Results. Significant differences between players, which appear to be influential on the kinetic chain, were identified. Each player has individual anthropometric characteristics, which explains both the personal technique and markers that may influence the serve, as each player has different results.

Conclusions. Using the MOTION GRID equipment as opposed to the Dartfish equipment ensures a better stability during the process of the double integration of the accelerometer data, whereas in the Dartfish equipment the technical execution may generate parallax errors, frequent in this measurement method.

Keywords: biomechanical parameters, tennis serve, inertial navigation sensors, video recording.

Rezumat

Premize. În tenis, fiecare procedeu tehnic este afectat de către tehnica jucătorului. Pentru a dezvolta un procedeu tehnic corect pentru un model de jucător, care îşi doreşte performanţa, trebuie să luăm în considerare mecanismele de lovire a fiecărei mişcări, în concordanţă cu caracteristicile fizice ale jucătorului.

Obiective. Analiza comparativă a unor metode de obiectivizare a parametrilor biomecanici ai serviciului în tenis.

Metode. Metoda de studiu experimental al serviciului este înregistrarea video, cu programul de analiza DARTFISH şi echipamentul cu metodologia de achiziție a datelor de cinematică, dezvoltată de către firma Xsens, Moven, care poate elucida problematica legată de valoarea şi particularitățile tehnice ale serviciului din tenis.

Rezultate. S-au observat diferenţe semnificative între sportivi, pentru indicii ce au o influenţă asupra lanțului kinetic. Fiecare dintre sportivi au caracteristici antropometrice individuale, fapt ce explică atât tehnica personală, cât şi indicele ce poate influenţa serviciul, fiecare sportiv având rezultate diferite.

Concluzii. 1) Utilizarea echipamentelor de tip MOTION GRID în comparaţie cu echipamentul Dartfish asigură o mai bună stabilitate în procesul de dublă integrare a datelor de accelerometrie, în comparaţie cu echipamentul Dartfish în care execuţia tehnică poate produce erori de paralaxă, des întâlnite prin această metodă de măsurare. 2) Dezvoltarea metodelor de măsurare, privind ameliorarea unei execuţii tehnice, va lua în considerare caracteristicile antropometrice individuale şi specifice, în acest caz comparaţia dintre sportivi va avea doar caracter informal.

Cuvinte cheie: parametri biomecanici, serviciul în tenis, senzori de navigaţie inerțială, înregistrare video.

Received: 2015, September 14; *Accepted for publication:* 2015, October 1;

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Introduction

Modern tennis is seen as a sports skill where every shot is executed differently. The player is required to go through the process of "Perception - Decision - Action - Feedback". According to the authors Crespo & Miley, 1998; Gottfried, 1994, when the technique is taught, focus must be placed on tactical intentions and biomechanics, while the technique will be approached as a procedure, rendering tactics more efficient. According to Groppel, 1997, the basic principles of biomechanics in tennis can be easily apprehended by the acronym "BIOMEC" standing for balance, inertia, reaction force, moment, elastic energy, coordination chain. Authors such as Kenichirou et al., 2011; Toshio et al., 2004 have studied the development of sports performance by using effective measurement devices. The role of spatial information in recognizing human and individual movements is the first step towards progress, by using a detailed pattern, which, in time, should lead to knowing one's own efficient style by way of movement perception (Pollick et al., 2001; Stirling et al., 2010). Each human movement is determined by a synergic action of the basic biomechanical units and its precision is calculated using mathematical formulas (Ivancevic & Ivancevic, 2008; Ivancevic et al., 2011). The muscle chain used for serving cannot be merely assessed based on an arm or upper body model; instead it implies the assessment of the entire kinetic chain, from the significant effect of the leg to the impact of the ball on the racket (Pansiot, 2009). This succession of movements is achieved through the coordination chain of the body, which, in the case of the serve is made up of the legs, torso, hip, shoulder-arm, joint (Temprado 2005; Durović et al., 2008). The kinematic analysis of the shot during the serve underlines the important contribution of the internal rotation of the upper arm in the development of the racket. Thus, the muscles in charge of this action should be trained (Elliot, 1995; Elliot et al., 2009). The studies of Girard et al., 2007; Sgrò et al., 2013 analyzed the impact of the movement of the knee when serving. The results indicated that the flexion of the knee before extension (elongation of the body to meet the ball with the racket) is a prerequisite for the effectiveness of the serve, regardless of the player's level.

The study used inertial navigation sensors. These were initially developed for military use, to determine position, speed, acceleration and movement, angular velocities and accelerations. These were derived from the navigational system of plane and ship autopilots.

To carry out inertial sensors, sensors for the simultaneous measurement of rotations around three mutually perpendicular axes are used, as well as sensors that are capable to break down the body acceleration, associated with three directions, identical to the above mentioned rotation axes (Fig. 1).

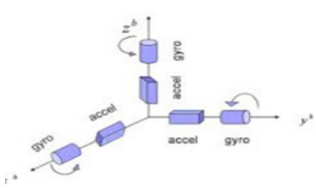

Fig. 1 – Operation principle of an inertial sensor (1).

The evolution of technology has made it possible for each of us to have such inertial sensors on our phones. Those used to pick-up motion in the MVN-BIOMECH technology are small enough not to bother the player and sufficiently precise to provide, after complex processing, the movement of the human body and of its segments. 17 such sensors are used in the making of the garment, placed as shown in Fig. 2.

Fig. 2 – Sensor fastening structure on the player's garment (3).

The inherent processes of integration of the acceleration data generate a "slip" of the body position and a tracking of one of the legs when lifted. To correct this error, the company manufactured and distributed an additional antenna system (Motion Grid), which stabilizes the data received from the player using a stapled reference in the horizontal and vertical movement. Being aware of the difficulties in correctly using the above presented product, we felt compelled to try another option for kinematic recording, that is, MVN-BIOMECH.

Objectives

This study aims to identify a method for assessing the tennis serve shot by comparing two objective measurement tools: Dartfish and Moven.

Hypothesis

The use of the MOTION GRID equipment compared to the Dartfish equipment ensures a better stability of the data when changing leg length and may fight the "drift" effect.

Materials and methods

This study was approved by the Ethics Committee of the Transylvania University, and the subjects' consent to participate in the study was obtained. The research protocol was based on a collaboration agreement between the Romanian Tennis Federation and the National Research Institute for Sport in Bucharest.

Protocol research

a) Time and place of the research

The locations used for conducting the experiment were: the National Tennis Centre, located on 11 Pierre de Coubertin St., 2nd Dist., Bucharest, and the National Research Institute for Sport, located on 41A Basarabia Av., 2nd Dist., Bucharest, between January and February 2015.

b) Subjects and groups

At the time of the recordings, Player S1 was 19 years old, with a 13 year experience in tennis and a national ranking, while internationally, he was ranked 150th in ITF. At the time of the recordings, Player S2 was 29 years old, with a 22 year experience in tennis and a national ranking, while internationally, he was ranked 100th in ATP.

c) Tests applied

- recording of the players' own services;
- recording of services for the two active players with different body structures.

The comparison of the results obtained for the two tests by recording using the classical method DARTFISH (2) and the product, MVN-BIOMECH.

Research phases

Preparation and acquisition of data from the tennis serve movement with two distinct phases:

- processing of the data collected/recorded for the two active players, the recordings made by us being used only as a personal filter regarding the acceptability of the technology in question in professional training and recording of serves;
- comparative analysis of the two methods considered for assessing the biomechanical parameters of the tennis serves.

Estimating the value of the DARTFISH product (2) for a large number of interesting and useful implementations in the field of sports, we may state that biomechanical applications are affected by coarse errors, given that it is very rare for the motion plane to be and remain perpendicular on the optical axis of the video or photo device. Even more so in the case of the tennis serve shot, where there is a rotational movement of the torso and of the hip from the beginning to the end of the active motion, distancing and approaching the body segments, hence corrupting the measurements of distances and angles.

Results

In Fig. 3, player S1 was evaluated by the Dartfish method. This assessment has a single angle of observation, depending on where the camera is positioned. In this case (Fig. 3), the measurement was performed behind the player.

Fig. 3 shows the result of a quasi-automatic angular measurement in one of the players, measurement that may be considered approximately correct given that the sole of the left foot as well as the leg and the thigh, with a slight error, may be considered to have a parallel direction with the court baseline, and the position of the recording device was chosen to be perpendicular on this line.

For those who regularly watch tennis matches, it is obvious that in the next phase both the hip and the torso, segments of the lower body, will follow curving trajectories, in forward motion, with the left side of the body moving away from the camera and the right side approaching the camera and offering other apparent dimensions of the segments.

Fig. 3 – Measurement of the angle between the leg and the thigh in the left leg of player S1.

Being aware of the difficulties in correctly using the above presented product, we felt compelled to try another option for kinematic recording, that is, MVN-BIOMECH. Just like with any other measurement device, we were aware that there were objections to the use of this product. Following a presentation of its operational principles, we will attempt to analyze the strengths and weaknesses related to its use.

We simultaneously performed video recordings and recordings of the parameters provided by the MVN-BIOMECH inertial navigation technology. As shown in the figures below, the players were always wearing the garment indicated in the previous chapter.

In order to exemplify the way in which the data were acquired, we highlighted images of the same serve, recorded from behind and from the side, to present the results of the kinematic recordings for two of the three players, S1 and S2.

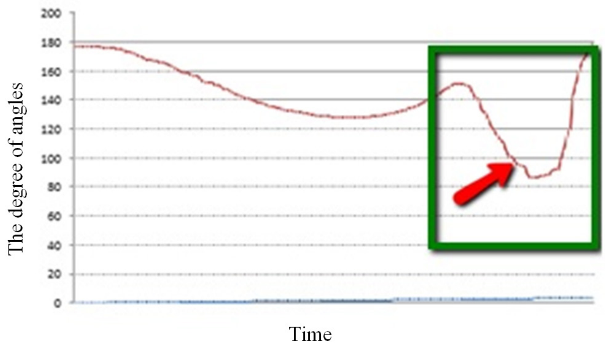

Fig. 4 – S1- Evolution of the thigh-leg angle in the left knee.

As an argument for the superiority of using inertial navigation equipment, we present in Fig. 4 the evolution in time of the thigh-leg angle in player S1, where the approximate point/moment of the player in preparation of the shot is marked with a red arrow. An additional outcome in this case is a clear image of the evolution in time of this angle and a clearer delimitation of the evolution of relative positions during the actual shot (green frame).

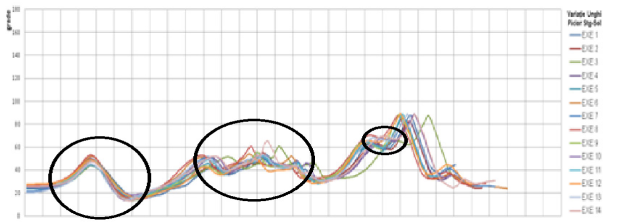

Fig. 5a – Variation of the angle between the pivot foot (left) and the floor in player S1.

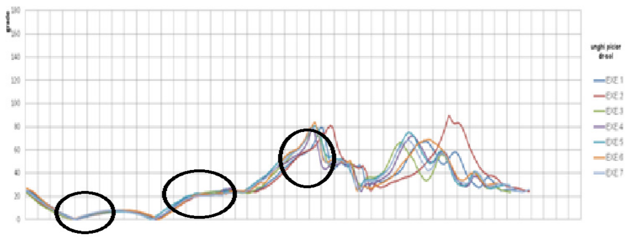

Fig. 5b – Variation of the angle between the pivot foot (right) and the floor in player S2.

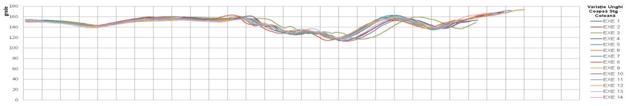

Fig. 6a – Variation of the ankle angle for the pivot foot (left) in player S1.

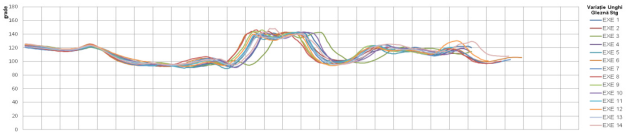

Fig. 6b – Variation of the ankle angle for the pivot foot (right) in player S2.

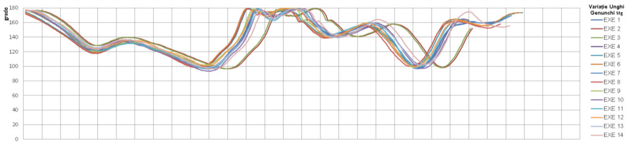

Fig. 7a – Variation of the thigh-leg angle for the pivot foot (left) in player S1.

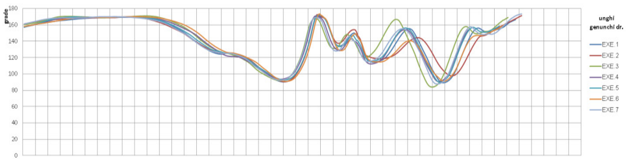

Fig. 7b – Variation of the thigh-leg angle for the pivot foot (right) in player S2.

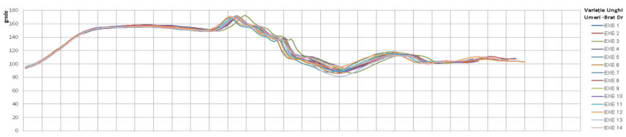

Fig. 8a – Variation of the angle between the shoulder line and the right arm in player S1.

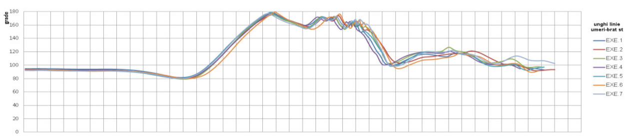

Fig. 8b – Variation of the angle between the shoulder line and the left arm in player S2.

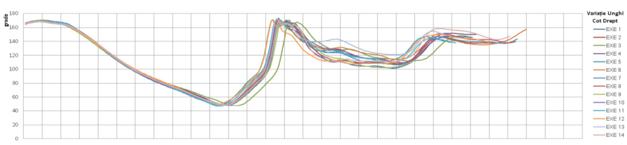

Fig. 9a – Variation of the arm-forearm angle in the right arm in player S1.

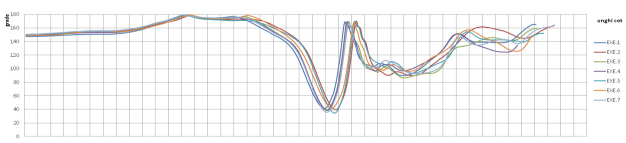

Fig. 9b – Variation of the arm-forearm angle in the left arm in player S2.

Discussions

As it can be seen in the diagrams, in the case of each player the curves are relatively grouped, which means that the movements in question are a well-rooted dynamic stereotype. It can also be said that both in the preparation phase and in the shot and movement closure phase, there are significant differences between the players; we consider these to be differences in style, as long as they do not indicate technical deficiencies or technical errors in the measured joint.

In Figure 5a (player S1), compared to Figure 6a, it can be seen that the preparation of the shot is delayed, when rising on tiptoes is required.

Player S1 systematically shows an initial rise of the heel followed by a descent and then a long interval when the angle between the foot and the floor is stabilized. After a short lift, the heel is elevated in two gradual steps until full stretch, which is possibly the highest stance, at the time of the shot.

Player S2 shows a smoother and more progressive lifting of the heel, but also a jump upon landing after completing the shot.

If we track the evolution according to the angle formed by the ankle joint on the side of the dominant hand, we find the same individual stability of the movement and behavioral differences between the players (Figs. 7a, 8a, 9a, 10). Player S1 behaves in a similar way to the situation of the angle between the foot and the floor; the player presents an extended time when the angle value is approximately 140^0, fully covering the shot area, while player S2 brings a powerful extension, possibly reaching at the moment of the shot a "peak" of 160^0, close to the maximum extension of 180^0 (Figs. 7a, 7b). We believe, and this is worth an additional analysis, that the impulsion performed by player S2 is much stronger and this may also relate to the fact that the player is shorter and, thus, needs this strength of impulsion to attain a jumping height, which ensures an increased efficiency of the serve.

In what concerns the recording of the angle relation between the leg and the thigh of the pivot foot, player S1 attains spring by flexion in two phases, while the lift up burst is milder, with the same stable aspect of the knee angle in its maximum stretch position. In player S2, after landing, the presence of certain continuous oscillations having the appearance of elastic waves can be seen (Fig. 7a).

Regarding the angle between the thigh and the spine/ torso, we can see a better uniformity in player S1 and the same flexion seen in the image analysis of the same player (S2). (Figs. 8a, 8b, 9a, 9b).

We analyzed only these 5 parameters of movement, as we considered them to be sufficient, at this stage, to underline the potential information yielded by the method and knowing that, beside the angles, we could also rely on: angular velocities and accelerations in each joint, stance, in Cartesian coordinates, of each extremity of the 23 segments into which the program divides the human body.

It is obvious that there is still a long way to go before understanding the meaning of each parameter and of the play between their evolutions, associated in an efficient movement, and that all information must be permanently related to the player's performance and features. This is particularly relevant since tennis is still a game where compensations can play a fundamental role. However, compensations only become useful when we have objective information on movement, when we know how to correctly interpret it and when we have the ability to recognize individual ways of developing performance, for each player.

MVN-BIOMECH provides a higher amount of data in comparison to the Dartfish method. It should be mentioned that the application of both methods might be of use from different perspectives. There is only one entry for the analysis of MVN-BIOMECH, whereas Dartfish examination provides at least four registrations (depending on the position of the camera).

Conclusions

1. Following the use of Dartfish programs for the recording of the main parameters in the tennis serve and the analysis and interpretation of the results, it was found that decisions cannot be made based only on one recording. It is very important for each technical execution to be analyzed from various angles, in order to avoid parallax errors, a frequent fault in Dartfish recordings.

2. We propose the use of the MOTION GRID equipment, which ensures a better stability of the data when changing leg length and may fight the "drift" effect, the shift of references that occurs due to the double integration of the accelerometer data.

Conflict of interests

There were no conflicts of interest, financial or otherwise.

Acknowledgments

This research exploits the partial results of the ongoing thesis at the Faculty of Physical Education and Mountain Sports, Transylvania University of Braşov, entitled "Outlining techniques for striking the ball in tennis serve".

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