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DYNAMIC BALANCE AND ITS DIAGNOSTICS BY USING 3D BIOMECHANICAL ANALYSIS

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Abstract. *The aim of this study was to gain a better view of dynamic balance abilities and offer a new special diagnostic mean. A three-dimensional biomechanical analysis offers excellent possibilities and is very helpful for effective sport preparation and an effective training process. Eight young tennis players, aged 16 to18, were tested on balancing a fitball in different positions. One of the most difficult positions – standing on the fitball with isolated upper extremities – the Budha position - corresponds very closely to the level of balance abilities which play a key role in high performance in tennis. This diagnostic mean can lead to very precise observations and can bring many exact outputs. The tested tennis players achieved very stable postures with values mostly ranging between 146 and 152 degrees. We also found some dominant work of the left knee. In addition, this body segment reached a higher acceleration (up to 3 m/s*^{2}*) than the same segment on the right side. This high velocity of each segment is needed to keep the balance and the peaks represent balance troubles with very quick corrections. At 10.090 s we can see a very stable position with velocities almost 0. They are 0.044 s for left knee and 0.068 s for right knee. Regarding acceleration, the situation is similar, but here we can see measurement at the same time (10.090 s). For reaching a very stable position, acceleration of the left knee (1.099 m/s*^{2}*) and decceleration of the right knee (-1.640 m/s*^{2}*) is needed. All these parameters are so precise that they are not visible to the naked eye. The obtained results are reasonable and characterize the dynamic balance of skilled athletes.*

Key words: *dynamic balance, three-dimensional biomechanical analysis*

INTRODUCTION

Many sports and physical activities require different levels of abilities and skills. The development of dynamic balance abilities plays a key role in most of them. Balancing on a fitball is a very interesting and useful exercise which is already established in sport

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preparation. Regarding the diagnostic process, in many cases the time for holding dynamic balance is the main criterion. But with help of 3 D biomechanical analysis, it is possible to achieve much more accuracy and different points of view (Baláž, 2005; Sebera et al., 2008). But this specific testing requires a very high level of balance skills and brain function as well. Polish authors (Stoklosa & Racek, 1999) found that the sense of balance depends on the regularity of the EEG and confirmed the influence of even the slightest brain dysfunction on the level of balance abilities. Another investigation (Witte & Blaser, 1999) based equilibrium on a chaotic process and used the model of a strange attractor. Their results for the dimension quantities showed statistically significant differences between tests under various conditions. Judge (2003) investigated balance changes with advancing age and confirmed that balance depends on sensory input, central processing (or motor control), and muscle strength and power.

Purpose

The purpose of this study is to offer a three-dimensional biomechanical analysis as a very precise diagnostic mean and balancing on a fitball as a suitable test for skilled athletes.

Methods

Eight young gifted tennis players aged 16 to 18 made up the experimental group of athletes with a high level of balance abilities. They were observed in two attempts. Each athlete was instructed to keep a balanced position as still as possible during a period of 20 seconds. Balancing on a fitball was realized in three different main positions (sitting on the fitball, standing on one's knees on the fitball and standing on the fitball (see Figs. 1, 2, 3) and three different sub positions.

Fig. 1. Sitting on the fitball

Fig. 2. Standing on one's knees on the fitball

Fig. 3. Standing on the fitball

The different sub positions were: 1. isolated upper extremities – the Budha position (Fig. 4) 2. free moving hands 3. hands on hips – akimbo.

All these positions were recorded by two synchronic video cameras. This conveys three-dimensional space which is real and very conducive for understanding how balancing works.

A three-dimensional biomechanical analysis with Simi motion 3D software allows us to find the exact values of the kinematic parameters. They are trajectories, angles, velocities and acceleration of each body segment. The accuracy was established on three decimal places.

These main anthropomotor segments (points, joints) were indicated with retroreflective markers and taken into consideration: the head, left arm, right arm, left elbow, right elbow, left wrist, right wrist, left hip, right hip, left knee, right knee, left ankle and right ankle. The ball as an extra segment was added and one retroreflective marker located in the center of the front part was included in the calculation (Fig. 4).

Fig. 4. Standing position Budha on the fitball with indicated retroreflective markers

As we can see on Fig. 5 the balance movement is possible in all three directions:
– axis x represents forward – backward movement
– axis y represents lateral movement
– axis z represents vertical movement

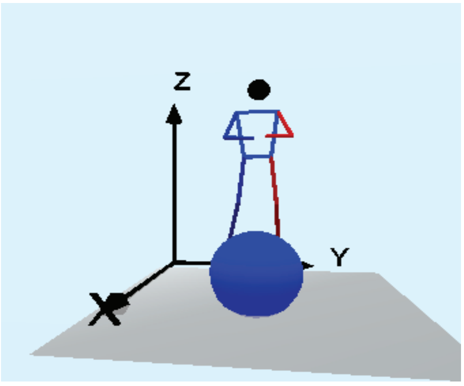

Fig. 5. Stick diagram and possible movements

The monitoring of all kinetic parameters can be realized along the x, y, z axes and as an absolute value as well.

Results and Discussion

Both attempts of each athlete were similar, while more differences appeared among the tested tennis players. Better results are connected to higher sport performance.

Precise work of both knees is shown in the following figures. Trajectories (absolute values) of the left and right knees are similar but not the same. It can clearly be seen that the left knee is doing stabilization work and with greater length. At 16.860 s there is a 1.797 m length for the left knee and 1.524 m for the right knee (Fig. 6).

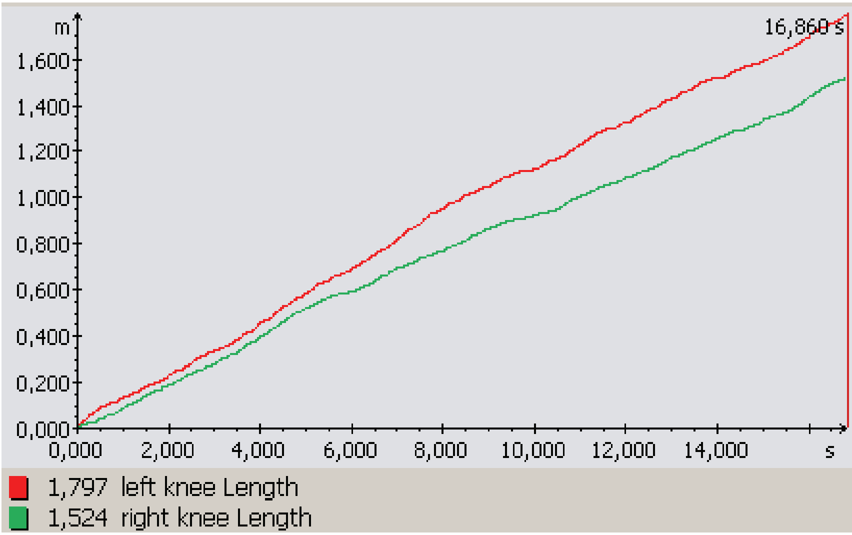

Fig. 6. Length of left and right knee (absolute values)

Compared to the knee differences, the work of the elbows is almost the same in the hands held together (the Budha position) case. The length for the left elbow is 1.237 m and 1.260 m for the right elbow (Fig. 7).

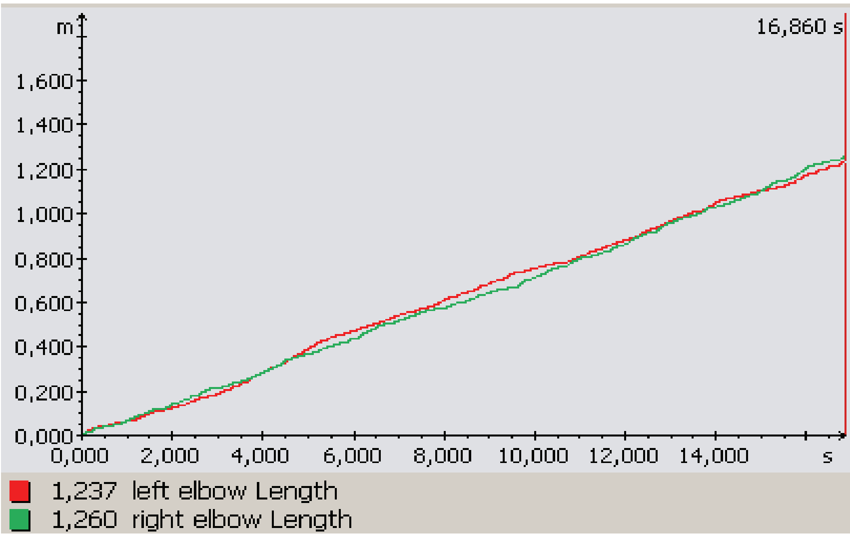

Fig. 7. Length of the left and right elbow (absolute values)

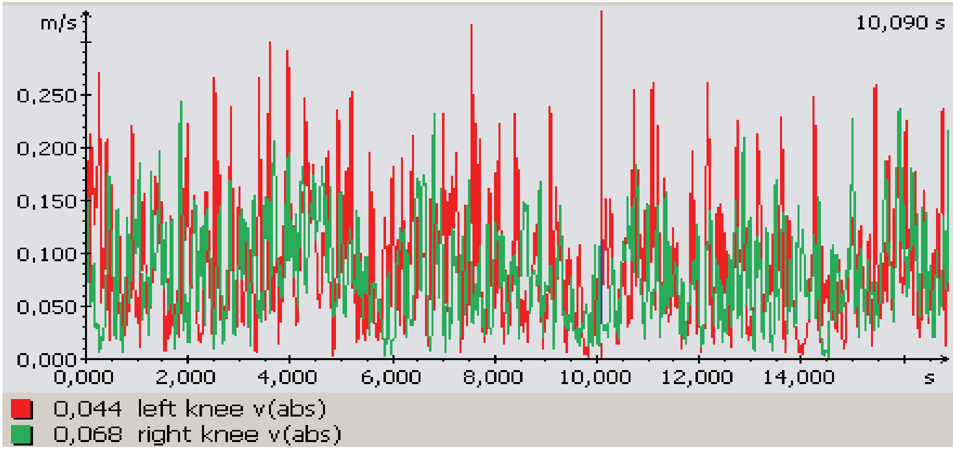

Fig. 8. Velocity of the left and right knee (absolute values)

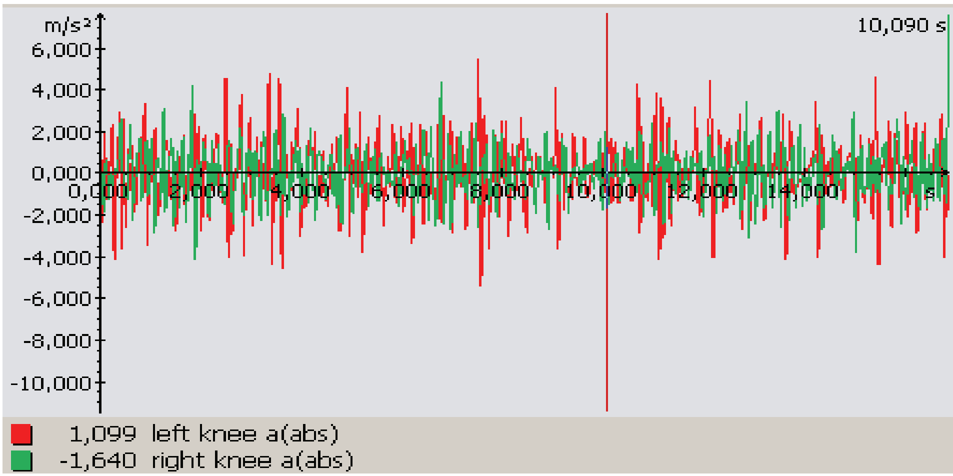

Fig. 9. Acceleration of the left and right knee (absolute values)

The record in Fig. 8 confirms the dominant work of the left knee; this body segment reaches higher velocity (up to 3 m/s^2) than the same segment on the right side. This high velocity of each segment is needed to keep balance and the peaks represent balance troubles with very quick corrections. At 10.090 s we can see a very stable position with velocities almost 0. They are 0.044 s for the left knee and 0.068 s for the right knee. Regarding acceleration, the situation is similar, but here we can see measurement at the same time (10.090 s) and for reaching a very stable position, the acceleration of the left knee (1.099 m/s^2) and the decceleration of the right knee (-1.640 m/s^2) is needed (Fig. 9). All these parameters are so precise that they are not visible to the naked eye.

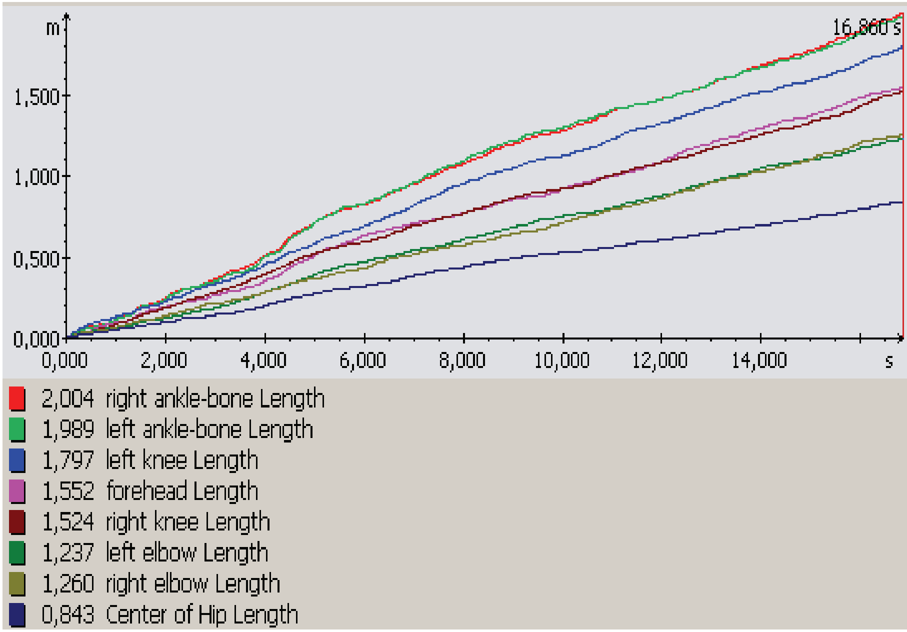

Fig 10. Trajectories of the chosen body segments during the trial (from bottom to top)

Figure 10 recorded the different body segments whose trajectories are different. The most stable body segment is the center of the hips with a length of 0.843 m (blue bottom line) which was calculated from the left and right hip parameters. On the opposite side, the biggest length was achieved by both ankles, and their lengths are 1.989 m for the left ankle and 2.004 m for the right ankle.

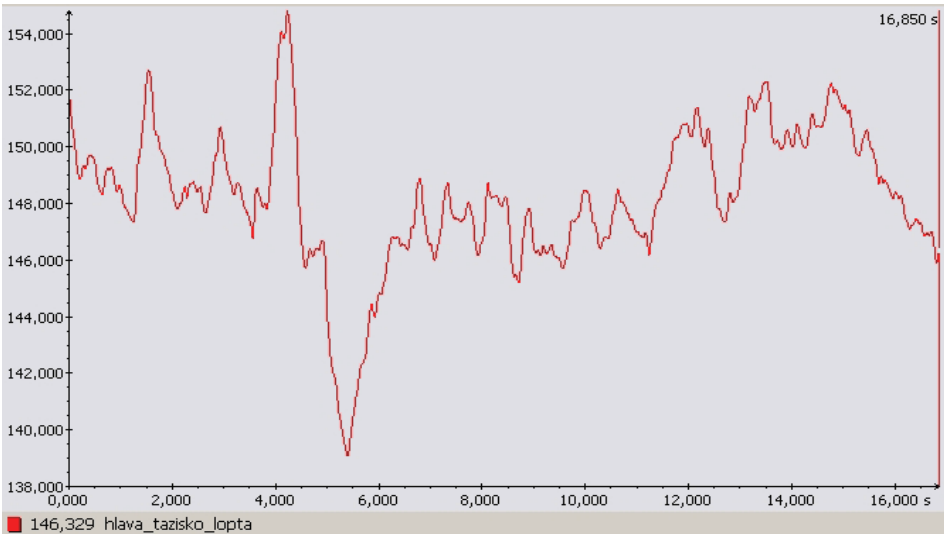

Fig. 11. Angle forehead – center of hips – ball and its changes

The tested tennis player achieved, in this trial, values that mostly ranged between 146 and 152 degrees. Extreme values at unstable moments had a maximum of 155 and a minimum of 139 degrees (Fig. 11). This not very wide interval is suitable for the tested athlete and characterizes his balancing posture.

Although there is some uncertainty regarding the mechanisms that underlie the variation in specific tension of muscle fibers, it is clear that this factor can contribute significantly to differences in strength among individuals. The magnitude of this effect is probably specific to each muscle and to the physical activity and sport levels. All this is very individual (Duvačová & 2004). These findings suggest that the coordination of activity within and across muscles has a significant influence on performance. These adaptations lead to postural maneuvers for the balancing task and the goal-directed movement itself.

Because the human body can be characterized as a linked mechanical system, it is necessary to orientate the body segments and to set the base of support on which the movement is performed.

Experienced and creative coaches apply new and special means, methods and exercises in training praxis which lead to achieving the highest possible performance (Veličković et al., 2006; Zemková et al., 2006, Čoh & Širok, 2007; Psalman, 2007; Ivančević et al., 2008). Since most sport are characterized by mostly unstable conditions, the need to use a very precise three-dimensional analysis which brings us many results from different points of view is evident.

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DINAMIČKA RAVNOTEŽA I NJENA DIJAGNOSTIKA 3D BIOMEHANIČKOM ANALIZOM

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Cilj ove studije je bio da se dobije dublji pogled na sposobnosti dinamičke ravnoteže i ponuda novog specijalnog dijagnostičkog značenja. 3D analiza pruža izvanredne mogućnosti i vrlo je korisna za efikasnost sportske pripreme i treninga. Osam mladih tenisera u dobi od 16 do18 godina su bili testirani u balansiranju fitnes lopte u različitim pozicijama. Jedna od najtežih pozicija - stoj na lopti sa izolovanim gornjim ekstremitetima - Budhi pozicija vrlo je bliska sa nivoom sposobnosti ravnoteže koja ima ključnu ulogu u vrhunskom tenisu. To dijagnostikovanje se može posmatrati vrlo precizno i doprinosi tačnosti u rezultatima. Testirani teniseri su imali stabilno držanje sa vrednostima uglavnom u rasponu između 146 i 152 stepeni. Našli smo i neki dominantni rad levog kolena i taj segment tela postiže veće ubrzanje (do 3 m/s^2) nego isti segment na desnoj strani. Ova visoka brzina svakog segmenta potrebna je za održavanje ravnoteže u trenucima brze korekcije. U vremenu od 10,090s može se videti stvarno stabilna pozicija sa brzinom gotovo 0.0. Ona je 0,044s za levo koleno i 0,068s za desno koleno. Što se tiče ubrzanja, to je slično, ali ovde možemo videti mere u istom vremenu za postizanje vrlo stabilnog položaja, ubrzanja levog kolena (1,099 m/s^2) i usporavanja desnog kolena (-1,640 m/s^2). Svi ovi parametri su tako precizni da ne mogu biti vidljivi samo uz pomoć vlastitih očiju. Dobijeni rezultati su razumni i karakterišu dinamičku ravnotežu kvalitetnih sportista.

Ključne reči: *dinamička ravnoteža, trodimenzionalna biomehanička analiza*