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Joint angles during successful and unsuccessful tennis serves kinematics of tennis serve

Başarılı ve başarısız tenis servisleri sırasındaki eklem açıları: Tenis servislerinin kinematiği

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Objectives: The aim of this study was to investigate the joint angle differences in successful and unsuccessful tennis serves of junior tennis players.

Patients and methods: Nine healthy junior tennis players (5 girls, 4 boys; mean age 11.8±0.8 years; height 153.6±7.2 cm; body mass index 42.3±4.1 kg; playing experience 6.2±1.5 years) volunteered to participate in this study. They were asked to perform tennis serves as fast as they can as if they were in an actual game. Successful and unsuccessful serves were recorded using two high speed cameras and then analyzed using Pictran software. Angle changes in pre-impact, impact and post-impact phases were compared.

Results: The results of paired sample t-tests revealed nosignificant differences between successful and unsuccessful tennis serves in all three phases.

Conclusion: This study failed to show differences between successful and unsuccessful tennis serves in pre-impact, impact and post-impact phases. However, future research with more detailed analyses would be needed to reveal the possible changes in the joints while serving.

Key words: Joint angles; kinematics; tennis serve.

Amaç: Bu çalışmada genç tenisçilerin başarılı ve başarısız tenis servisi atışları arasındaki eklem açı farkları incelendi.

Hastalar ve yöntemler: Dokuz sağlıklı tenisçi (5 kız, 4 erkek; ort. yaş 11.8±0.8 yıl; boy 153.6±7.2 cm; vücut kütle indeksi 42.3±4.1 kg; oyunculuk deneyimleri 6.2±1.5 yıl) çalışmaya katılmak için gönüllü oldu ve gerçek tenis maçında olduklarını varsayarak atabilecekleri kadar hızlı servis atışı yaptı. Başarılı ve başarısız servis atışları saniyede 60 resim kaydedebilen iki adet kamera ile kaydedildi ve daha sonra Pictran yazılımı ile analiz edildi. Topa vuruş öncesi, vuruş anı ve vuruş sonrasındaki eklem açıları karşılaştırıldı.

Bulgular: Bağımlı değişkenler t-testi ile analizi yapılan bu üç vuruş safhasında başarılı ve başarısız servisler arasında anlamlı bir fark görülmedi.

Sonuç: Çalışmanın bulguları servis atışının vuruş öncesi, vuruş anı ve vuruş sonrası safhalarında başarılı ve başarısız denemeler arasında bir fark olmadığını ortaya koydu. Servis atışı sırasında olası eklemsel değişikliklerin ortaya çıkartılması amacıyla daha detaylı incelemelerin yapılması gerekmektedir.

Anahtar sözcükler: Eklem açı farkları; kinematik; tenis servisi.

The serve in tennis is the most effective shot that can influence the result of the game.[1] It has gathered much attention due to its popularity, which in turn leads the researchers to focus on the factors affecting the speed of the ball during a tennis serve. The flat serve is the more commonly used type of serve

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compared to the slice serve.[2] There are several aspects, such as the characteristics of both the racquet and player that may affect one's ability to serve at high speeds.[3] Using the whole body in an integrated manner can really improve the power of the serve. The motion begins at the feet, flows up to the knees and legs, uses the hips and body weight and then allows the upper body and arms to strike the ball. This is called the kinetic chain and it uses all of the body parts efficiently in stroke production.[3] An ineffective use of the body segments, in contrast, brings a high risk for joint injury, especially for the shoulder, elbow and wrist, which are the last parts of the kinematic chain. The potential to cause injury seems to be related to high internal forces (combination of muscle and joint reaction forces), particularly where these forces are associated with a poor technique and high segment accelerations. The injury risk increases when the racket moves behind the body and the vertebral column is laterally flexed and hyperextended.[4] The pronation of the forearm and the forces associated with the swing towards the ball, the impact and the early follow-through are also factors with a potential to cause injury.

The lower limb movements starting with plantar flexion followed by the knee extension play an important role in generating the moment for an effective and powerful serve. Girard et al.[5] reported the knee to be a significant contributor to serving effectiveness whatever the performance level is.

The upper limb kinematics was investigated in some studies and its importance was pointed out[6,7] indicating that the segment endpoint velocities increase from proximal to distal aspect and follow a shoulder-to-elbow-to-wrist-to-racquet-center sequence like throwing. During this movement, the shoulder rotates externally prior to rotating internally and the range of motion during this rotation is approximately 80 degrees.[7] There is also a 52 degree rotation in the forearm in the acceleration phase of the serve. The role of this pronation is to correctly position the racquet head in preparation for impact. The wrist extends in the contact phase and then rapidly flexes in the acceleration phase. This flexion of the wrist has been reported to be a major contributor to racquet velocity.[8] It can also be observed that the wrist changes its position from radial deviation to ulnar deviation, which seems to be a natural continuation of the wrist flexion movement and puts the racket into a vertical position. The external rotation of the shoulder, the wrist extension and the twist rotation of the lower trunk are found to contribute to the racket speed during a tennis serve.[9]

In their study, Van Gheluwe and Hebbelinck[10] found that the rotation of the hand relative to the ground contributes to 51-75% of the final velocity of the racquet, while the contribution of the rotation at the wrist was much less than this (0-11%). Sprigings et al.[11] expressed the velocity of the racquet head as a function of the linear velocity of the hitting shoulder, the angular velocity of the upper arm, and the angular velocities at the elbow and wrist joints. According to their results, the forward velocity of the racquet head at impact is generated mainly by the internal rotation of the upper arm, rotations on the transverse axes of the upper arm, and the wrist flexion. These rotations accounted for 85-98% of the forward velocity of the racquet at impact, while the elbow extension actually made a negative contribution to the forward velocity of the racquet head at the impact.

One of the most important reasons of injuries in tennis is the wrong execution of the different strokes. Lateral epicondilitis (tennis elbow) is the most common one and it occurs if the players do not extend their elbows fully during a forehand stroke. The player's technique plays a very important role in generating the power during a service, which on the other hand brings a high risk of injury. Therefore, players have to use their body segments in coordination. The segment angles are one of the indicators of a correct technique. Keeping the elbow, knee and hip in a flexed position at the impact phase causes so many problems in generating a successful serve.

Understanding the roles of different body parts on the effectiveness of a tennis serve is expected to help us to develop training sessions and at the same time lessen the injury risks due to its execution with a false technique. The difference between the successful and unsuccessful performances would also assist us in understanding the common mistakes during the tennis serve, which in turn gives us the chance to correct these mistakes. In this respect, the purpose of this study was to find out the angular joint differences between successful and unsuccessful tennis serves. We hypothesized significant angle differences in segment angles of junior tennis players.

Figure 1. Dragonfly express.

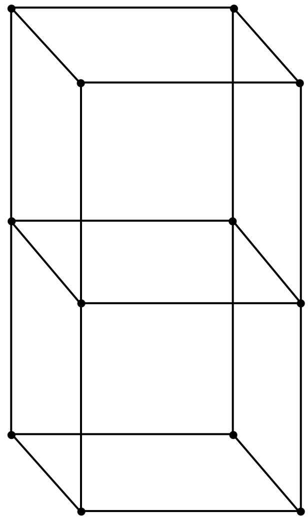

Figure 2. Calibration cage.

PATIENTS AND METHODS

Participants

Nine experienced junior tennis players (5 girls, 4 boys; mean age 11.8±0.8 years; height 153.6±7.2 cm; body mass index 42.3±4.1 kg; playing experience 6.2±1.5 years) participated in this study. Since the participants were under the age of eighteen, appropriate approvals and consents were collected from the parents and the participants. All participants were free of injury and had a tennis experience of at least five years. All participants were from the tennis club of the Middle East Technical University, Turkey.

Materials

Participants wore tight clothing during the experiment. The experiments took part in the closed tennis court. Reflective markers were placed on the elbows (lateral epicondyle), shoulders (Acromium process), hips (greater trochanter), knees (lateral condyle), ankles (lateral malleolus) and toes (5^{th} metatarsophalangeal joint). The tennis serves were recorded at a stereoscopic view with two digital cameras (Dragonfly Express, Point Grey Research Ottawa, Canada) at a frame rate of 60 Hz (Figure 1).

The cameras were placed at approximately a 90 degree angle to each other. A cage with the dimensions of 1.0x1.0x2.0 m at 12 control points was used to calibrate the space, in which the instep penalty kicks were performed (Figure 2). Photogrammetric restitutions were conducted using the Pictran software (Technet GmbH, Technet Pictran Release 4 Digital Photogrammetry, Berlin, Germany). The adjustment process was conducted in bundles of 6-8 control points. Three dimensional coordinates of the marked points were defined after the adjustment process was completed. Ankle extension and knee flexion were determined from the images.

Procedure

The procedure was explained to the subjects before the experiment. After a 15-minute standard warm-up session, participants served the ball from the

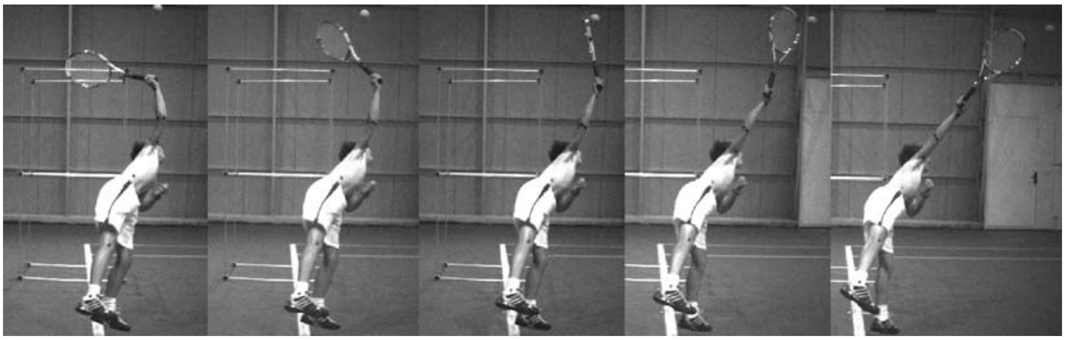

Figure 3. Camera view during the execution of tennis serve.

TABLE I

Successful and unsuccessful angle differences of ankle, shoulder and elbow joints

	Pre-impact	Impact	Post-impact
Ankle			
Successful	75.67°±12.87°	77.44°±13.03°	80.74°±15.12°
Unsuccessful	72.70°±9.78°	76.67°±10.51°	81.41°±12.02°
Shoulder			
Successful	160.74°±20.33°	172.11°±16.41°	180.30°±23.75°
Unsuccessful	157.93°±20.60°	170.07°±19.72°	174.41°±21.05°
Elbow			
Successful	181.33°±10.45°	196.44°±10.61°	221.98°±18.98°
Unsuccessful	182.44°±12.24°	199.78°±13.74°	228.89°±21.12°

right side of the court. Five successful and five unsuccessful flat serves were recorded. Players were told to serve the ball as fast as they could, as if they were in actual game conditions.

The synchronized pictures of pre-impact, impact and post-impact positions obtained from the two cameras were digitized and then ankle, shoulder and elbow joint angles were analyzed using Pictran software.

Paired Sample t-test was used to compare the angle differences between successful and unsuccessful tennis serves in pre-impact, impact and post-impact phases.

RESULTS

The angular changes in ankle, shoulder and elbow are shown in Table 1. We conducted Paired sample t-test to test the differences of ankle angular changes between unsuccessful tennis serves of junior tennis players. The results showed no significant ankle angle differences in pre-impact ($t(8)= 1.3$, $p<0.05$), impact ($t(8)= 0.4$, $p<0.05$) and post-impact phases ($t(8)= –0.5$, $p<0.05$). For the shoulder, the results also revealed non significant differences for pre-impact ($t(8)= 0.9$, $p<0.05$), impact ($t(8)= 0.5$, $p<0.05$) and post-impact phases ($t(8)= 1.2$, $p<0.05$). We couldn't find any significant differences for the elbow angular changes in pre-impact ($t(8)= –0.4$, $p<0.05$), impact ($t(8)= 0.6$, $p<0.05$) and post-impact phases ($t(8)= –2.2$, $p<0.05$) either.

DISCUSSION

Joint angles in tennis serve play an important role in the success of the player. During the service, the body should be moved in a well developed kinematic chain in order to generate the necessary power. Even small changes in the joint angles can cause the ball to fly beyond the service area. A wrong technique may also play an important role in increasing the risk factors for the injury. In this regard, the purpose of this study was to compare the angle differences between successful and unsuccessful serves of junior tennis players.

The results of the statistical analyses showed no significant differences between the successful and unsuccessful tennis serves in pre-impact, impact and post-impact phases for ankle, shoulder and elbow joints. The findings were found to be consistent with the previous results of a study conducted by Gordon and Dapena[9] in which no significant contribution was found for the elbow extension. When interpreting the results and planning future research, it should be considered that the present study has certain limitations, like the limited number of the participants and the lack of some other kinematic variables.

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