NEW BIOMECHANICAL MODEL FOR TENNIS SERVE

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Preliminary communication paper

Abstract
A sample of 70 professional ATP players was used to perform an analysis of serve in the game. Digital snapshots of the matches have been used for the purpose of analysis. Each player had 10 successfully performed serves analyzed. Sophisticated 3-D Motion Analysis System with accompanying Software was used within the analysis. The main goal of the work was to establish biomechanical regularities of the correct, orderly and effectively performed serve through 3-D analyses of the serve. The secondary goal was to establish the model that explains correct and biomechanically justified performance of the serve, which model could in the future be put into function of teaching young and perspective tennis players, as well as for technical tactical corrections of top players, at least for choosing tactics that involve serve. The established model is made up from 8 variables (A-H) and functions flawlessly while giving the opportunity to conclude and explain generally as well as specifically. The best technique of serve, and the goal of every player is to master it to perfection, will allow the complete control of performing this action with the least risk of injury.

Key words: *tennis, center of gravity, kinematic service analysis*

Introduction

Tennis belongs to the category of polystructural complex movements of the acyclic type (Bahamonde, R.E. and Knudson D., 1998, Groppel, J. L., 1986).Success of the tennis player is determined by the level and structure of numerous skills, knowledge, abilities and qualities, most of which can be measured (Ivančić T., Jovanović B., Đukić M., Marković S., Đukić N.2008) . Each body movement is conditioned my muscle work and physiological processes that happen simultaneously. At the same time, gravity, either positively or negatively, influences the weight or in other words the mass of the sportsman making him efficient or inefficient in realizing that movement (Anderson, M. B., 1979., Bahamonde, R.E. and Knudson, D., 1998., Enoka, R.M. 2001). The movement will be efficient if it was performed, in the biomechanical sense, correctly, and if possible optimally (Knudson, D., & Morrison, C., 2000). Tennis serve is the most complex shot performed in the game and its technical performance doesn't depend on the opponent. It is necessary to master the serve to perfection, and there are many obstacles in the way, such as: Trying too hard-using too many muscles; Forehand grip; Looking down to the court before hitting.

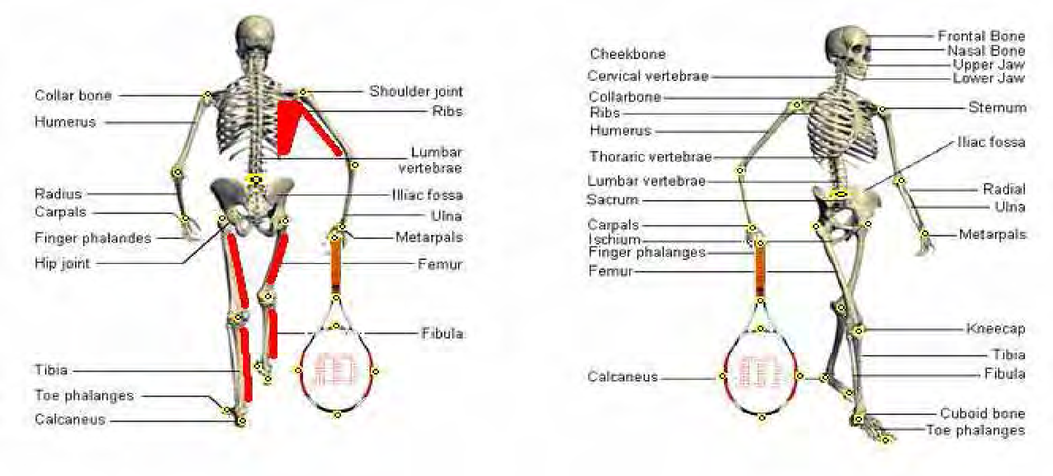


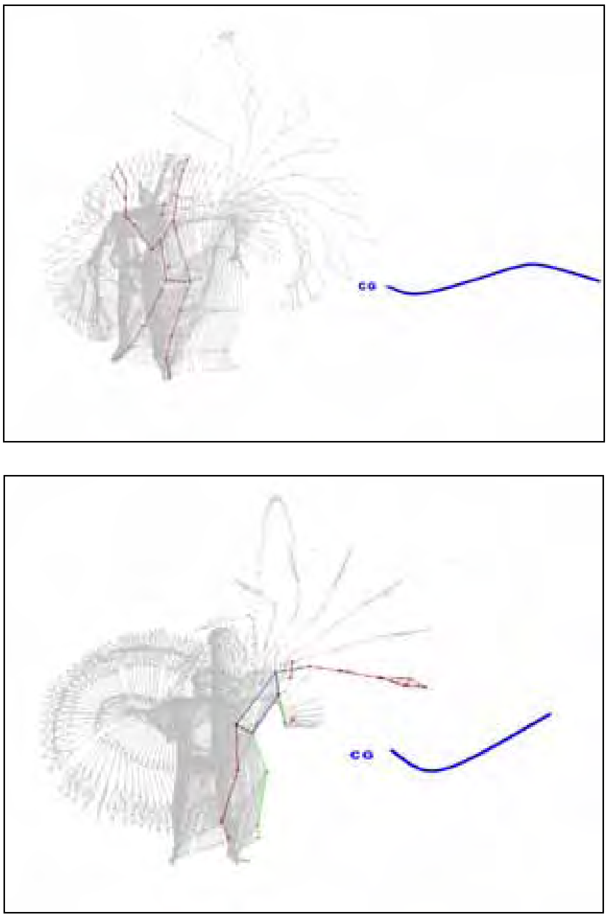
Figure 1.Elements for analysis of the tennis serve (By authors of article)

The efficient serve will be performed only when a player, in a movement that is biomechanical correct, connects a big force with big speed, or in other words acceleration, which will consequently transmit to the tennis ball. Only a strong, but at the same time fast player can learn to serve efficiently (Cauraugh, J. H., Gabert, T. E., and White, J. J.,1990). In the last 30 years the strength of the players is obviously constantly growing and has a tendency of further growth. In the work of author (Gideon B. Ariel, Ph.D.) there is a description and analysis of jump while serving. The jump itself has absolutely no relevance but is a consequence of the kinetic chain that forms and happens during the serve. The concept connected with the behavior of the centre of gravity and balance is necessary to understand the correct serve. Bad balance or loss of balance is one of the most common mistakes when serving (Elliott B, Reid M, Crespo M, eds., 2003). Center of gravity (OTC) is a point in which player's mass is concentrated hypothetically. When serving, through the legs, the general center of gravity is informed about the trajectory which is unchangeable after the last contact with the surface, unless outer forces influence it. A pivotal role for correct and efficient realization of the optimal serve is now given to trajectories of the segmental gravity centers in relation to the general gravity center. Balance in the technique of tennis serve is analyzed and described in the phase of static like in the dynamism of serve, generally by speculative descriptive methodology and in general formulations. Shortly, some analyzed authors dominantly analyze the serve by descriptive-speculative method, and even when they solve the problem by exact scientific methods (3-D Kinetic analysis) in the end they choose the descriptive option (Chow, J.W., Carlton, L.G., Chae, W., Shim, J., Lim, J. & Kuenster, A.F. 1999., Elliott, B., Marsh, T., and Blanksby, B. 1986., Ivančić T., Jovanović B., Đukić M., Marković S., Đukić N., 2008., Van Wieringen, P. C. W., Emmen, H.H., Bootsma, R.J., Hoogesteger, M., and Whiting, H. T. A., 1989.)

Goal and methods

The primary goal of this work is to establish biomechanical regularities of the correct, orderly and effectively performed serve through 3-D analysis of serve of 70 professional players. The secondary goal is to create and establish a model that explains correct and biomechanical justified performance of serve and to put it in function of teaching young and perspective tennis players in the future.

1. Sample of subjects (Sample consisted of 70 ATP players with extraordinary achievements in tennis. Four of them were ex Nr.1. at the world ATP list: Agassi, Federer, Sampras and Kuerten.)
2. Method of collecting data (Digital snapshots of real matches and segments of serve at ATP tournaments with selection of 10 quality and successfully performed serves)
3. Methods of processing data (Sophisticated 3-D Motion Analysis System with accompanying Software was used for analyzing data: APAS – Ariel Performance Analysis System 2000).



Picture 1. Scheme model for serve analyses

Results and discussion

A model was established on the basis of past research and knowledge of biomechanics of the tennis serve, on the experience of the authors and some previous exploring.

Model is made as the graphical review shows 8 criteria for correct biomechanical serve

KINETIC SERVE NEW MODEL
1. SIGNIFICANTLY FLEXED KNEES TO MAKE USE OF GROUND REACTION FORCE (GRF) TO BEGIN THE SUMMATION OF FORCES
2. DISTURB BALANCE – EXTEND ARM-HIPS GOING FORWARD
3. SHOULDER BEGIN TO ROTATE AWAY FROM THE NET
4. INTERNAL ROTATION OF THE UPPER ARM AND FOREARM PRONATION
5. HAND FLEXION
6. BODY LANDS INSIDE THE BASELINE WITH TRUNK FLEXED FORWARD
7. LEFT / RIGHT HIP FOLLOWS CG TRAJECTORY
8. CG ALLWAYS GOING FORWARD

Explanation of the elements of the model

The model consists of 8 criteria:
A. GRF (Ground Reaction Force) - starts after significantly flexing the knees (summation of forces towards racket)
B. Disturbed balance, extended arm position in a way that allows hips moving forward
C. Shoulders begin to rotate aside from the net position
D. Internal rotation of the upper arm and forearm pronation
E. Hand flexion
F. Body lands inside the baseline with trunk flexed forward
G. Left and right hip follow OCG trajectory
H. OCG continues to move forward until gaining balance for new activity

Picture 2.Method of shooting the serve

Picture 3. All-court player

Based on behavior of the OCT trajectory analysis we establish legitimacy of continuous OCT movement to the forward during the tennis serve in all cases. Two typical trajectories appeared and they were described in our article as well as reasons why they appeared and what causes them. There is always a succession of movement expressed through one-motion acts and in the case from the previous page open kinetic chain. It is obvious from the kinematic review and real snapshots of the serve of two top world players that they serve completely different but successfully because they both fulfill all 8 criteria. In both cases everything happens according to do scenario of the model as it follows:

A. GRF (Ground Reaction Force) - summation of forces towards racket starts after significantly flexing the knees (Van Gheluwe, B. and Hebbelinck, M., 1986)
B. Disturbed balance, extended arm position in a way that allows hips moving forward

C. Shoulders begin to rotate aside from the net position

D. Internal rotation of the upper arm and forearm pronation

E. Hand flexion accelerates the ball additionally and ends the mechanic chain when racket hits the ball

F. Body lands inside the baseline with trunk significantly flexed forward

G. Left and right hip follow OCG trajectory

H. OCG continues to move forward until gaining balance for new activity.

Differences that fit into the existing criteria and are a consequence of a game style are obvious in these two players and manifest themselves as follows: Left and right hip follow the trajectory of the center of gravity of both players, but serve volley player has a more distinct movement towards, since his aim is to be on net as soon as possible, while the trajectory of the all-court player goes upwards as his intention is to remain on a base line after serving. Similarity in the way of serving is obvious between all-court player with defensive game and offensive baseline players because they also have a tendency of remaining on a baseline after serving.

Conclusion

The model that has been established in this work obviously functions flawlessly and gives the opportunity to conclude and explain generally as well as specifically. Efficiency of the shot depends on kinetic parameters of performing the overall movement, as well as on the anthropological characteristics of the players, tactical components such as timeliness of choosing kick, flat, spin or slice serve depending on how well the player „reads“ the opponents game and his bad sides. Jump while serving has absolutely no relevance but is a consequence of the kinetic chain that forms and happens during the serve. In the case when a blockade of the trunk rotation is done during the serve (by the arm under the chest) the transition of the force moves to another connection or in other words to shoulder-elbow-wrist. That kind of serve is 1.7 times faster than the serve without the blockade of the trunk rotation (Gideon Ariel, Ph.D.).One needs knowledge of how to stop a certain body segment and to transfer force to the following connection in the chain. Results of this work will allow and contribute to the choice of the work methods at the tennis serve training at the tennis schools and will enable technical tactical corrections of top players, at least for choosing tactics that involve serve.

The best technique of serve is the one that contains both the maximum force and speed and full control of the act performance with the least risk of injury. Only the perfect coordination of the named elements will allow improvement of the power control-no injuries scheme.

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NOVI BIOMEHANIČKI MODEL TENISKOG SERVISA

Sažetak

Uzorak od 70 profesionalnih ATP igrača je korišten za izvođenje analize teniskog servisa u igri. U svrhu analize su korišteni digitalni snimci mečeva. Za svakog igrača je analiziran set od 10 uspješnih servisa. Sofisticirani ''3–D Motion Analysis System" s odgovarajućim pratećim softwareom je upotrijebljen za analiziranje. Glavni cilj rada je bio utvrđivanje biomehaničkih zakonitosti korektnog, urednog i učinkovito izvedenog servisa kroz 3-D analizu. Sekundarni cilj je bio utvrđivanje modela koji objašnjava korektni i biomehanički opravdano izvedeni servis, a koji model može u budućnosti biti stavljen u funkciju obučavanja mladih i perspektivnih tenisača, baš kao i za tehničko-taktičke korekcije vrhunskih tenisača, u najmanju ruku za izbor taktičkih djelovanja koja uključuju servis. Ustanovljeni model je koncipiran kroz 8 varijabli (A–H) i funkcije koje daju besprijekornu mogućnost zaključivanja i objašnjenja, kako općenito tako i specifično. Najbolja tehnika servisa, kao cilj svakog tenisača, je da je usavrši do perfekcije i omogućava potpuni nadzor izvođenja ove akcije s minimalnim rizikom od povrijeđivanja.

Key words: *tenis, središte težišta, kinematička analiza servisa*

Received: August, 14. 2008.
Accepted: December, 10. 2008.
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