

Kinematics of Lower Extremity in Tennis Flat and Spin Serve

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Abstract

The purpose of this study was to explore the biomechanics of the two different serving patterns—flat serve and spin serve. In conjunction with force plates that helped to measure the ground reaction force (GRF) and worked out the center of pressure (COP), a motion analysis system was used to discover the 3-D kinematic changes of the ankle, knee, hip, pelvis and trunk in the overall serving motion in the study. The moment formed by COP with the whole body center of mass would then be analyzed to investigate the kinematic characteristics of the body. The further understanding of the role of joints in the lower extremity during a serve will provide a reference for motions and techniques of training and teaching, with views to improve serving efficiency and to avoid sports injury.

Keywords: Tennis, Serve, Kinematics, Lower Extremity

Introduction

The serve is one of the most important techniques in tennis. Tennis serve can generally be divided into three patterns: flat, spin, and slice. Tennis serve transfers the ground reaction force (GRF) to the trunk by tiptoeing, utilizing an effective integrity of body segments and the continuity of limb motion from proximal end to distal end.

Elliot and Wood (1983) used force plates to compare the two techniques, foot-back and foot-up, during the serve, and the results showed that foot-up used the effective momentum of the lower extremity with greater vertical GRF and higher impact point. On the contrary, the horizontal GRF of foot-back was greater, and the first step for volley after serve was closer to the net. van Gheluwe and Hebbelinck (1986) compared the influence of the three GRFs during the serve. The results showed that the horizontal reaction force was not obvious, but vertical reaction force was more obvious at the preliminary stage. The greatest force came from the vertical reaction, reaching 1/3 of body weight. Groppel (1992) pointed out that the transition of angular momentum from the GRF through body segment to the racket was the most unfamiliar concept in tennis research. Thus kinematics of the trunk in the tennis serves and GRF-related studies appeared to be important.

Methods

Six elite and experienced male tennis players (age: 28.2 ± 9.2 yrs, height: 175.82 ± 5.6 cm, body mass: 71.9 ± 4.2 kg) in tennis singles and doubles, without any history of upper extremity symptoms participated in this study. All the subjects

used the same Prince mid-sized tennis racket when collecting the serve motion data. The HiRES Vision Motion System (Motion analysis Corp., Santa Rosa, CA, USA) was used in the experiment. Six-video cameras were placed around the subjects at 120 Hz to collect trajectory image data of the subjects' limb motion during the serve. The subjects stood on two Kistler forceplates, with the frequency at 1000HZ, to measure the GRF of feet during the serve. Before the experiment, calibration was required to work out the space coordinate system of the laboratory. The calibration procedures were as follows: place three cameras on each side of the subjects, and adjust their positions and aperture to have all the eight markers on the steel fixture be captured by at least two cameras. Through VCA and EVA software, and input of the distance among the eight measured marks, the lab coordinate system could thus be built. In addition, another 21 markers were placed on the players' main anatomical positions, such as styloid process of radius, lateral epicondyle, acromion, anterior superior ischial spine, mid-thigh-cuff with marker on wand, lateral knee plateau directly lateral to axis of rotation, mid-shank-cuff with marker on wand, lateral malleolous, heel, the 2nd & 3rd metatarsal head, and sacrum. The markers' position vectors were first collected as basic points when the subjects were standing to modify the difference between the marker-defined coordinate system and anatomical coordinate system. The subjects stood on two forceplates, one foot on each plate, to facilitate the collection of dynamic image data. After the trigger was launched, each subject executed a flat serve and a spin serve with two arms up. Each serving motion was collected 5 times for obtaining average value. The subjects performed the four phases of serve: wind-up, cocking, acceleration and impact. Each trial lasted for 5 seconds with 3-minute rest between trials.

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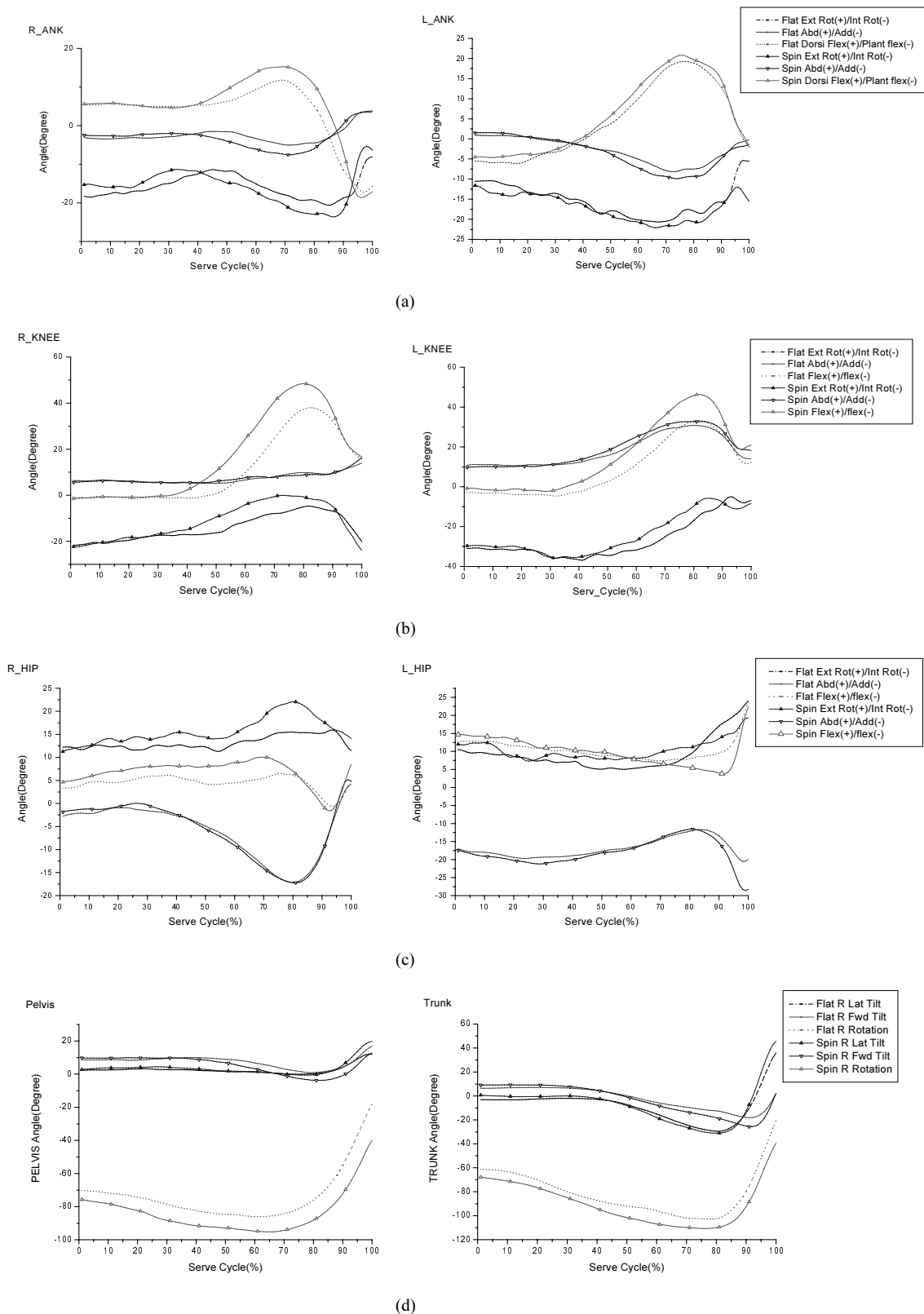


Figure 1: 3-D kinematics data of the lower extremity and trunk

Results and Discussion

Time parameter

It took 3.06 and 3.22 seconds to complete tennis flat serve and spin serve respectively. The time that each of the phases

took up is shown in Table 1. Tough the spine serve took a little longer time than flat one, there was no statistically significant difference between the two. During the serve, most of the time was spent on throwing, impact, and racket drop. Acceleration period accounted for only 1/10 of the serve cycle.

Table 1: Time spent on different serving patterns (N=6)

Cycle	Time(Sec)	
	Flat Serve	Spin Serve
Ball release	1.14±0.27	1.14±0.25
Racket drop	1.60±0.11	1.77±0.15
Wind-Up—Cocking—Acceleration	0.31±0.04	0.31±0.02
Total serving time	3.06±0.32	3.22±0.39

3-D kinematic data of the lower extremity and trunk (see Figure 1)

The major motions of the ankle for both flat serve and spin serve are dorsiflexion and plantarflexion. Initially, the left foot had a slight plantarflexion for 5 degrees, then had a flexion towards dorsiflexion during mid-racketdrop, and reached the maximum of 18-degree dorsiflexion during acceleration. Next, the foot produced a “tiptoe” towards plantarflexion. On the other hand, the right foot had been on the condition of 5-degree dorsiflexion from the beginning, and reached the maximum of 10-degree dorsiflexion during acceleration, then produced a “tiptoe” towards plantarflexion, and reached the maximum of 20-degree plantarflexion before impact.

The major motions of the knee for both flat serve and spin serve are flexion and extension. At the beginning, the knees did not bend; however they started to bend at mid-racket drop, and reached the maximum during acceleration. At this moment, the largest flexion angle of the spin serve was approximately 50 degrees, and the largest bend angle of the flat serve was 30 degrees. In other words, tennis players bent the lower extremity more often in the spine serve than in the flat one. The lower extremity would straighten back before impact.

During the entire serving cycle, the hip bent all the way, and only straightened to 0 degree before impact, and bent again immediately. At the beginning, the left foot abducted 20 degrees, and started to adduct at mid-racket drop, reaching the maximum of 10-degree abduction during acceleration, then started to abduct. The right foot maintained natural from the beginning, then started to abduct at mid-racket drop, and reached the maximum of 15-degree abduction, then started to adduct.

The pelvis at the beginning rotated externally, and did not start to rotate internally until acceleration. The difference between the flat serve and spin serve was there are more backward pelvis tilting in spin serve during acceleration, which may reach approximately 0 degree and 5-degree. The trunk at the beginning rotated externally. In dorsiflexion, the trunk reached the maximum before impact, around 25 degrees for the spin serve, and 18 degrees for the flat serve. In right-side bend, the trunk reached the largest angle at the end of acceleration for both serves, 25-degree right-side bend, and then went on left-side bend.

Conclusion

From the data of 3-D kinematics of the lower extremity and trunk and body moment, we can conclude that the spin serve produces more lateralflexion moment than flat serve, and this moment comes mainly from the lateralflexion of the trunk. This point can be verified by the 3-D kinematics results of the trunk. In addition, in the data of 3-D kinematics, the spin serve has a significant difference from the flat serve: the former produced more knee bend than the latter during acceleration, and more backward pelvis tilting. This will help to increase the momentum during the serve and its transfer. From this study, we can further understand the role of joints in the lower extremity during a serve and will provide a reference to motions and techniques on training and teaching, with views to improve serving efficiency and to avoid sports injury.

References

- [1] Elliot BC, and Wood GA, “The biomechanics of the foot-up and foot-back tennis service techniques”, *The Australian Journal of Sport Sciences*, 3(2): 3-6, 1983.
- [2] Groppe JL, High-tech tennis. Champaign, IL: Human Kinetics, ch.8: 145-169, 1992.
- [3] van Gheluwe B, and Hebbelinck M, “Muscle actions and ground reaction forces in tennis”, *International Journal of Sport Biomechanics*, 2: 88-99, 1986.