ANKLE KINEMATICS OF CUTTING MOVEMENT DURING VOLLEY IN TENNIS

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The purpose of this study was to investigate the ankle kinematics of cutting movement during volley in tennis. Three male tennis players performed three cutting angle movements (0°, 30° & 60°, represents by S0, F30, F60, respectively) to volley a dropping ball with racket. Kinematics of the ankle was recorded by three-dimensional (3D) motion analysis system. During the early stance (the first 30% from heel strike), the results showed difference in the kinematics parameters in the three cutting angle movements for each subject. During late stance (last 30% before foot off), the mean values of everison and plantarflexion angles with F60 are largest in three cutting angle movements, so are the angular velocities. Therefore, the subjects may select different strategies to avoid foot injuries after heel strike. Furthermore, movements of the foot in performing the F60 may increase Achilles tendon injuries and medial tibial stress syndrome before the foot leaves the ground during the tennis volley.

KEY WORDS: volley, cutting movement, biomechanics.

INTRODUCTION:

Tennis is one of the most popular sports in many countries. It involves powerful movement that includes moving quickly in all directions, changing directions often, stopping and start, while maintaining balance and control to hit the ball effectively. It has been found that more injuries of tennis players occur at lower extremities (injury rate: 39% ~ 59%) than at the upper extremities (Plum et al., 2006). The lower extremities injury rates for the ankle are 16.7~27.8%, and the ligament sprain is one of the most common injuries in ankle joints.
Pervious studies have examined the lateral movement by two-dimensional analysis in order to investigate the motion characteristic of ankle. Ankle inversion during the lateral movement took place within 50ms after touchdown had been observed (Stacoff et al., 1996). The excessive inversion could increase the ankle injure (Gudibanda & Wang, 2005). So far, there have been few studies to discuss about ankle motion during cutting movement by three-dimensional (3D) analysis (McLean et al., 2004; Ford et al., 2005). Therefore, the purpose of this research attempts to understand and compare the 3D ankle kinematics of three type of cutting movement during the tennis volley.

METHOD:

Data Collection: Three right-handed male tennis players without history of lower limb injury volunteered for this investigation (age: 20.7 ± 0.6; height: 171 ± 3.6 cm; mass: 66.3 ± 13.0 kg), and they have been playing tennis for 3 years. The experimental procedures were for the subject prepared at the start line to perform cutting movement. The location height of the Styrofoam ball (instead of a tennis ball) was 256.5cm. The subject holding the racket with his right hand stretching out can just hit the dropping ball when he stood at the center of the force platform with his right foot. The force platform (Kitsler, Type 9281B) was being placed at approximately two steps (about 2 meters) away from the start line and the platform was used to determine the ground reaction force (GRF). The subject was asked to perform three cutting angles (0°, 30° and 60°) movement with the same tennis shoe (Adidas012508; size US: 9.5). The definition of cutting angle as followed: the forward lateral cutting defined as moving forward at angle of 30° (F30) and 60° (F60) and sideward lateral cutting defined as moving sideward at angle of 0° (S0). While performing an open stance forehand volley under each cutting angles movement, the subject would place his right foot on the force platform which occurred at the same time as the contact of the ball was been made with the racket. Approaching speed to the force platform was about 3.07 ± 0.16 m/s. However when each cutting angles was performed, the subject must come back to the start line at 0° as soon as possible after accomplishing the volley. The detailed description can view Figure 1. In order to collect the data of 3D kinematics by eight-cameras video system (Motion Analysis Corp., Santa, Rosa, CA, US), and twenty reflective markers were attached to the subjects on each different lower body location recommended by Helen Hayes Static Marker Set. During the experiment, both the motion analysis system (200Hz) and the Kitsler's force platform (1000Hz) were activated at the same time.

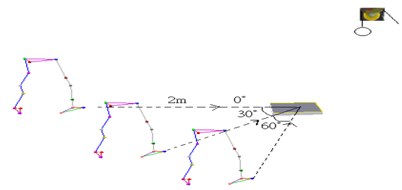


Figure 1: motion movement

Data Analysis: The raw data of kinematics and GRF were collected by EvaRT (Version 4.4.1, Motion Analysis Corporation). The angles of ankle were obtained by OrthoTrak (Software 6.2.4, Motion Analysis Corp) and a Butterworth with a cut-off frequency of 6Hz was applied to the data. A 10N threshold was used to determine the time at touchdown with the force plate and at toe-off (TO) from the vertical GRF. After all the GRF data were used to filter out the data collected at the frequencies above 100Hz. The following variables were extracted form each trial during stance-phase: the angles of in/eversion ($\theta_{In/Eversion}$), dorsi/plantar flexion ($\theta_{D/PF}$) and peak angular velocity (ω) were displayed in early stance and late stance. The total angle displacement ($\triangle\theta$) was calculated by the differences of peak angle to the angle of initial contact and that of toe-off in early and late stance-phase respectively. Early stance is defined as the first 30% of the stance phase and late stance is defined as the 70% ~ 100% of the stance phase.

RESULTS:

The kinematics of the ankle joint is presented in Fig. 2. In/eversion angles at the instant of foot contact are near to 0°. The in/eversion and dorsi/plantar flexion patterns with different cutting angle movements are similar during the early and late stance phase, except that subject 1 has larger variation during late stance phase (the kinematics parameters show the opposite values for S0 and F30). During early stance, the kinematics parameters of subject 1 decrease with increasing cutting angles; opposite values are observed for subject 2 compared to subject 1; the kinematics parameters are not influenced by the three cutting angles for subject 3 (table 1). During the late stance, the subject 2 and the subject 3 display that the kinematics parameters of F60 are largest in the three cutting angle movements, and the kinematics parameters increase with an increase in cutting angle, except the Peak $\omega_{In/Eversion}$ of subject 2. However, results of subject 1 show that the kinematics parameters are not influenced by the cutting angle, and only the kinematics parameters of F60 (the mean values are negative) are similar to those for other subjects during the late stance phase (table 1).

DISCUSSION:

In early stance, previous study examined the lateral movement by 2D analysis, the result displayed that the peak of inversion in early stance (stacoff et al., 1996; Gudibanda & Wang, 2005). Ankle inversion hardly occurred with the three cutting angles movements examined in the current study (Fig 2). The discrepancy of the results in the previous studies might be caused by the limitation of foot positioning in early stance (Fig 3). Comparing with the current study, the inversion with different cutting movements during early stance are similar to running and walking (Stacoff et al., 2000 and Branthwaite et al., 2004), the value of peak eversion angular (-97~108°/s) is in the range of peak angular velocity for walking (-95°/s) and running (-132°/s).

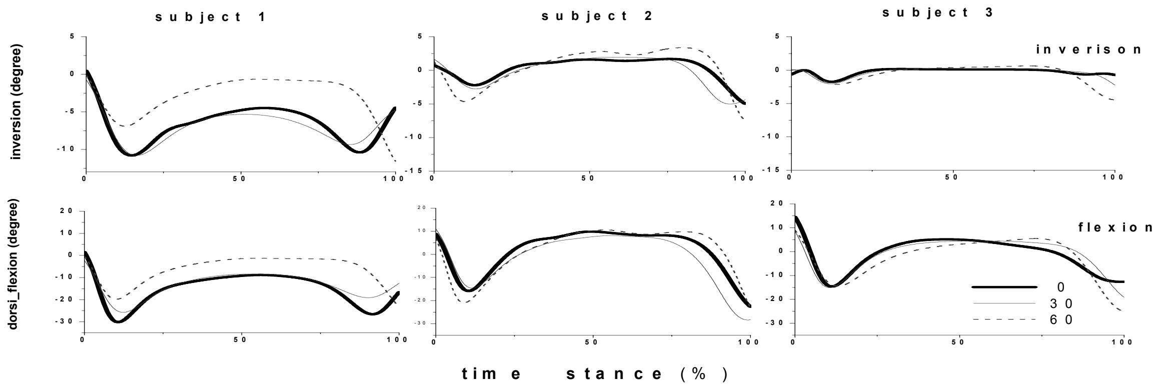


Figure 1: Means curve of in/eversion and dorsi/plantar flexion of three cutting angle movements for the three subjects: (—) 0°, (—) 30°, (– –) 60°.

Table 1 Mean values (standard deviation) of the parameter studied.

Variable	Cut angle (°)	Subject1	Subject2	Subject3
Early stance				
$\triangle\theta_{In/Eversion}$ (°)	0	-11.3 (2.2)	-3.2 (0.6)	-1.12 (0.9)
	30	-10.3 (3.7)	-4.8 (0.9)	-2.7 (0.5)
	60	-7.3 (1.4)	-6.0 (0.7)	-2.34(0.9)
$\triangle\theta_{D/PF}$ (°)	0	-31.8 (3.7)	-25.4 (4.4)	-29.4 (4.0)
	30	-23.9 (5.3)	-26.4 (3.9)	-24.7 (2.8)
	60	-20.0 (2.8)	-28.8 (2.6)	-24.2 (2.6)
Peak $\omega_{In/Eversion}$ (°/s)	0	-180.4 (37.7)	-58.9(10.3)	-51.6 (18.9)
	30	-163.8 (51.4)	-84.8(22.9)	-57.4 (11.4)
	60	-143.1 (23.5)	-122.9(17.2)	-58.2 (17.2)
Peak $\omega_{D/PF}$ (°/s)	0	-675.0 (68.7)	-543.6 (60.0)	-546.6 (76.6)
	30	-490.0 (90.1)	-556.2 (82.0)	-509.1 (86.1)
	60	-467.8 (57.5)	-673.5 (33.9)	-468.3 (43.9)
Late stance				
$\triangle\theta_{In/Eversion}$ (°)	0	5.9 (0.6)	-6.9 (4.0)	-0.1 (1.6)
	30	4.4 (10.2)	-6.3 (2.8)	-2.5 (1.0)
	60	-10.5 (2.9)	-11.4 (1.4)	-5.1 (0.8)
$\triangle\theta_{D/PF}$ (°)	0	10.1 (2.6)	-32.2 (13.8)	-6.8 (19.8)
	30	5.0 (17.9)	-35.3 (5.2)	-21.0 (19.5)
	60	-20.7 (7.6)	-35.0 (3.6)	-31.1 (2.6)
Peak $\omega_{In/Eversion}$ (°/s)	0	119.2 (10.8)	-90.82 (39.7)	-4.1(39.8)
	30	85.3 (135.3)	-97.3(49.2)	-42.5(37.9)
	60	-105.2 (119.0)	-164.1(30.5)	-80.4 (6.5)
Peak $\omega_{D/PF}$ (°/s)	0	264.7 (68.7)	-398.6 (74.7)	-123.1 (282.6)
	30	180.5 (272.2)	-386.4 (88.3)	-242.6 (294.0)
	60	-214.5 (241.4)	-486.6 (92.1)	-391.5 (14.3)

Note: positive values represent inversion, and dorsiflexion; negative values denote eversion, and plantarflexion.

The three subjects perform different strategies with different cutting angle movements during early stance, but subject 2 and subject 3 seem to display the same strategies with different cutting angle movements during late stance (kinematics parameters of F60 are highest in the three cutting angle movements). However, subject 1 only utilized plantarfleixon and eversion in F60 during late stance. Pervious researches assumed that excessive eversion and eversion velocities of foot during running or walking have been linked to Achilles tendon problems and medial tibial stress syndrome (Clement et al., 981; Viitasalo & Kvist, 1983). And Wang,Tu & Chiu (2007) discovered that the occurrence of maximum Achilles tendon force was close to the moment when the ankle joint changed form dorsiflexion to plantarflexion, likely the early and late stance in present study. In this study, a unique risk factor could be individualized depending upon the subject's performance with different cutting angles during early stance. Stiles and Dixon's (2006) assumed that task-oriented skill on sport movements may result in different strategies selected by the subjects in order to copy with different surface conditions. Thus, a task-oriented movement (hit the ball) may result in greater inter and intra-subject variability. The three subjects perform different strategies with cutting angle movements to avoid injuries during early stance. In aspect of late stance, the F60 may have largest Achilles tendon injury in this study.

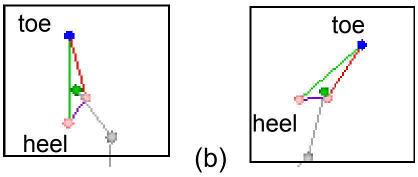
(a) (b)


Figure 3: The type of foot positioning with inversion (a) and eversion (b).

CONCLUSION:

The present results compared with lateral movement, the ankle inverison has not been found during the forehand tennis volley which might be caused by the limitation of foot positioning. Therefore, the lower extremity injuries in tennis examined by previous study are not suitable. During early stance, subjects may select different strategies to avoid injuries before they hit the dropping ball successfully. However, movement of foot in performing the F60 may increase Achilles tendon injuries and medial tibial stress syndrome before foot leaves the ground during the tennis volley.

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