The Role of Ground Reaction Force between Different Tennis Serves

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Introduction
Serve is the most important technique in tennis and usually classified into three patterns: flat serve, spin serve and slice serve. However, the ground reaction force (GRF) and its effects on body movements between different serve patterns are rarely known. The purpose of this study was to investigate the GRF and its moment arm about the whole body center of mass (COM) during flat serve and spin serve in the wind-up, cocking, and acceleration phases.

Methods
The HiRES Expert Vision motion system (Motion Analysis Corp., CA, USA) with six cameras was used to quantitatively collect the trajectories of the reflective markers at sampling rate of 120 Hz while the subject performed tennis serve. Twenty-one markers were placed on selected anatomic landmarks to define the position of each body segments. 13-segment model was used to calculate the whole body center of mass (COM). Two Kistler forceplates (Kistler Instrumente AG, Winterthur, Switzerland) were used to measure the GRF for each leg at 1000 Hz, respectively. Six Taiwan national tennis representatives were recruited in this study. The whole body COM, GRF for two legs and center of pressure (COP) were computed and represented in the global coordinate system (Fig. 1). The angular body movement potential caused by the ground reaction was represented by the moment arm of the whole body ground reaction with respect to the whole body’s COM.

Results
Fig. 2 shows the body weight transfer during flat serve. In the beginning of serve the body weight was supported evenly by two legs, and then shifted to back limb in the phase of wind-up. In the phase of cocking, the body weight shift was reversed and transferred to the forward limb in acceleration phase. The magnitude of fore-after shear forces was greater than medial-lateral shear forces. Similar force pattern can also be found in spin serve.

The moment arm of GRF about the whole body COM around the X (fore-after) - and Z (vertical)-axes had the similar pattern between two types of serve (Fig. 3). The Z-axis moment arm, vertical rotation potential during serve, was small and close to zero. Hence, the moment arm around X axis, rotation potential around fore-after direction, increased in wind-up, then gradually decreased in the cocking phase and was close to zero in the acceleration phase. In contrast, the moment arm curve around Y (mediolateral)-axis was different between flat and spin serves, especially in the acceleration phase. In the acceleration phase, the spin serve showed a peak flexion moment arm, i.e. GRF causes greater flexion moment for the body.

Discussion
The flexion-extension moment arm in flat serve is longer than that in spin serve in wind-up and cocking, but smaller in acceleration phase. It means that spin serve
requires greater whole body flexion moment. The power of different serves was mainly from the movement of trunk rotation and bending. The moment arm of GRF about the whole body COM may give this valuable information. In flat serve, the main power is in fore-after direction with less trunk rotation and bending. To the contrast, in spin serve, the rotation of trunk especially in acceleration phase is required to cause the spin of ball and the bending trajectory. Hopefully, the understanding of angular body movement potential in terms of the moment arm of GRR will be helpful for tennis training.

Fig.1: The trajectory of COP and projection trajectory of COM related to the forceplate and two legs during spin serve.

Fig.2: The ground reaction force normalized to total body weight of two forceplate during flat serve. $f_{1x}$, $f_{1y}$ and $f_{1z}$ are three components of left foot contact force. $f_{2x}$, $f_{2y}$ and $f_{2z}$ are three components of right foot contact force.
Fig. 3: The components of moment arm of GRF with respect to COM during flat serve and spin serve. FlatMRx, flatMRy and flatMRz are moment arm around fore-after, mediolateral and vertical axes during flat serve, respectively. SpinMRx, spinMRy and spinMRz are moment arm around fore-after, mediolateral and vertical axes during spin serve.

References