SWITCHING THE HORIZONTAL GRF TO THE PATH OF PROGRESSION IN THE TABLE TENNIS FOREHAND DRIVE

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Knowing the kinetic strategies of the lower limbs is a crucial factor to investigate the forehand drive which comprises the changes of the foot placement. It is difficult to directly evaluate the movement of feet with the data of ground reaction force (GRF) and impulse (GRI).This study tried to analyze table tennis forehand drives via the GRF and GRI data based upon the anatomical perspective. The motion and the GRF data were collected from eight right-handed Taiwanese elite table tennis players. The horizontal GRF data were transformed to a reference frame and then integrated with time to get the GRI. During the forehand drive shot, the participants performed a greater lateral impulse to cause the trunk rotation and decelerated their body from initial to mid-phase and then accelerated the body to perform a forehand drive shot.

KEY WORDS: path of progression, GRI, COM.

INTRODUCTION: Table tennis is one of the most popular indoor sports around the world. The forehand drive shot is the fundamental and crucial skill of the sports. The data of external force like GRF and GRI can show us the kinetic strategies of lower limbs. But there are some problems that existed, when the initial foot placement on the force plate do not coincide with the direction of motion or the axes of the force plate. It is difficult to understand the meanings of the components of GRF and GRI, especially the horizontal GRF via the outputs of force plates.

To evaluate the kinetic strategies of rotating segments is important for more understanding of the internal force and the moment among the multi-joints. Many investigators have provided some important data, such as the joint moments and powers, through the process of the inverse dynamics. Those data are interpreted in terms of body reference frames based on the anatomical view of point. Their efforts offer the readers a clear and visual understanding of internal mechanism of joints of the rotational sports such as discus throw (Yu, Broker, & Silverster, 2002) and shot put (Peng, 2006). However, the aspect of external force, such as horizontal GRF and GRI data, are presented in terms of global rather than local coordinate systems. It is difficult to know how the horizontal GRF and GRI perform on the body without expressing them in terms of body reference frames.

During the table-tennis forehand drive shot, the path of progression of the players differ with time in the global reference frame. We can use the horizontal coordinate changes of the path of progress of COM to convert horizontal GRF and GRI. The GRF data were transformed into a reference frame whose origin was the body center of mass (COM) and aligned to the COM trajectory and then integrated to find the GRI (Glaister, Orendurff, Schoen, & Klute, 2007). The purpose of this study was to investigate the horizontal GRF and GRI of two kinds of forehand drives.

METHODS: Eight right-handed Taiwanese elite table tennis players (male, age 23.8±3.4 years) participated in the experiment. The players were free from lower extremity problems in six months. Forty-nine reflective spherical markers were attached on the participants. The anthropometric measurements of the body segment parameter definition were following the Vicon Plug-In-Gait model (Vicon Peak, Lake Forest, CA, USA). Four reflective spherical markers were attached on the table tennis racket. Some reflective powder moistened covered on the ball to define the phases of the movement. Each participant's movements were captured by 10 Vicon MX13$^+$ high speed digital camera system sampling rate at 250 Hz. The GRF data were recorded by one Kistler 9287B and one 9281B11 force plates at 1000 Hz. The kinematics data were filtered with a low-pass Butterworth at 6 Hz. The COM of the participant was calculated based on the segment parameters of Dempster (1955).

During the process of data collection, the server (C) who was the table-tennis coach served a top-spinning and cross-table directional ball to the circle (A) and the receiver hit the ball straight back with forehand drive to (B) (forehand topspin-straight, FTS) or to (C) (forehand topspin-cross, FTC). Figure 1 depicts the schematic experiment setup of this study. The definition of successful trial was the combination of the height of hitting-ball not exceeding the fifteen centimeters from the top of the net and falling onto the rectangle (B) or (C). The forehand drive shot were defined by the motion date as four distinct phases including the preparatory movements phase, backswing phase, forward swing phase, and follow through phase. Only the horizontal GRF data of the right foot of the participants during the last two phases (FFP) were analyzed.

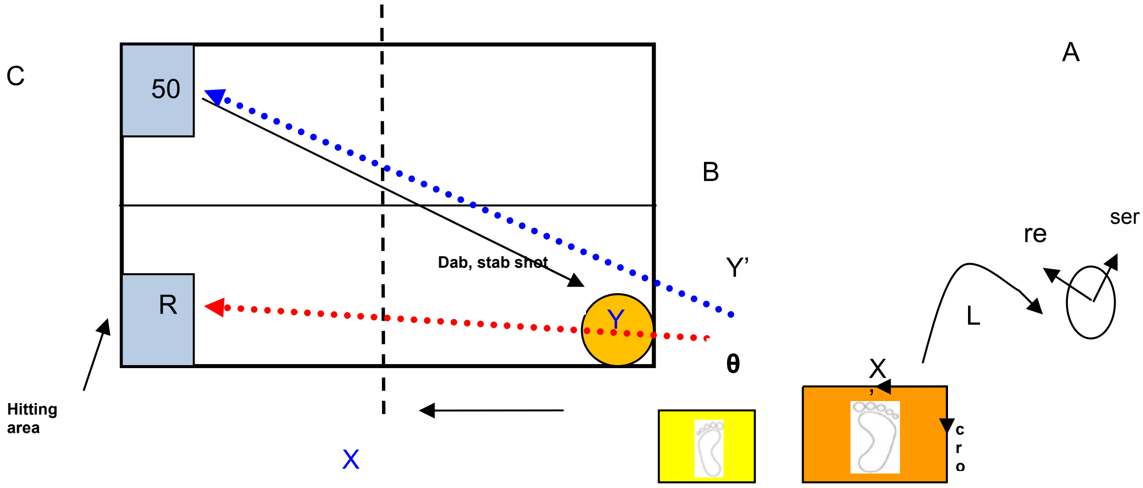

Figure 1: The schematic experimental setup. The global reference frame was defined by X and Y while the local reference frame is defined by X' and Y'. θ is the angle between the two reference frames.

This study adopted the method of Glaister, et al (2007) to create the local coordinate system (LCS). Origin location was chosen at the body COM. Axis alignment was determined by a two-point finite difference method, and the angle between the global reference frame and local reference frame was calculated. When the angle (θ) was obtained, the horizontal GRF were rotated about the vertical axis to each local coordinate system. The angles between the two reference frames were calculated as:

$$\theta = \tan^{-1}\frac{Y_j - Y_i}{X_j - X_i} \qquad \begin{bmatrix} F'_x \\ F'_y \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} F_x \\ F_y \end{bmatrix}$$

Where F_x and F_y are the horizontal GRF outputs from the force plates, and F'_x and F'_y are resolved GRF. Y_j, Y_i, X_j,and X_i are the Y and X positions of the COM in horizontal global coordinates at particular moments in time.The anterior–posterior (A-P) and medial–lateral (M-L) force vectors were integrated to compute the braking, propulsive, medial and lateral GRI. Braking and propulsive impulses were defined as those that acted opposite and in the direction of forward progression, respectively. Medial and lateral impulses were defined as those that acted to push the body away and towards the contralateral limb, respectively. The resolved GRF were normalized with body mass (kg) and GRI were normalized with body mass (kg) and % FFP using Microsoft excel 2003 and OriginPro7. The GRI of two kinds of forehand drive from forward swing phase to follow through phase was compared using student t-test at a .05 significance level.

RESULTS: Figure 2 depicted the ensemble average anterior-posterior GRF and medial–lateral GRF for the two kinds of forehand drives. There was a similar kinetic pattern existed in both kinds of drive shots. The braking and lateral GRF appeared firstly and then the propulsive and medial GRF followed. The durations of braking and lateral GRF were 45% and 60% of the FFP, respectively. Figure 3 depicted the scalar impulse in the A-P and M-L direction. During the forehand topspin-straight (FTS), the values of a braking impulse and a propulsive impulse were 45.1 ±33.6 and 46.7 ±27.9 N-%FFP/kg body mass. A prolonged impulse in the lateral direction (105.1 ±30.8N - %FFP/kg) existed and followed by the brief impulse in the medial direction (17.4 ±13.4 N - %FFP/kg). During the forehand topspin-cross (FTC), the values of a braking impulse and a propulsive impulse were 44.2±33.3 and 50.9±19.6 N-%FFP/kg, respectively. A prolonged impulse in the lateral direction (108.2±32.8 N-%FFP/kg) existed and followed by the impulse in the medial direction (16.9 ±10.0 N-%FFP/kg).There were no significant differences among these comparisons between both kinds of drive shot.

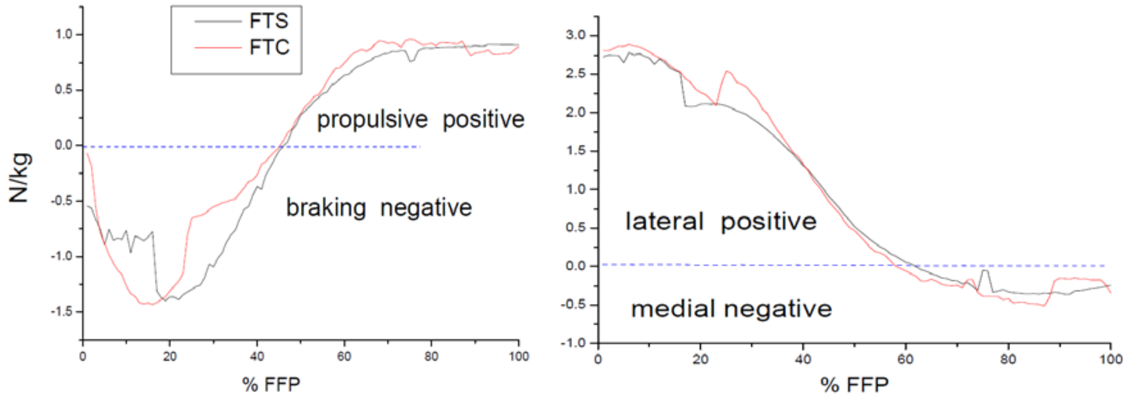

Figure 2: Ensemble average Anterior–Posterior GRF (left) and Medial–Lateral GRF (right).

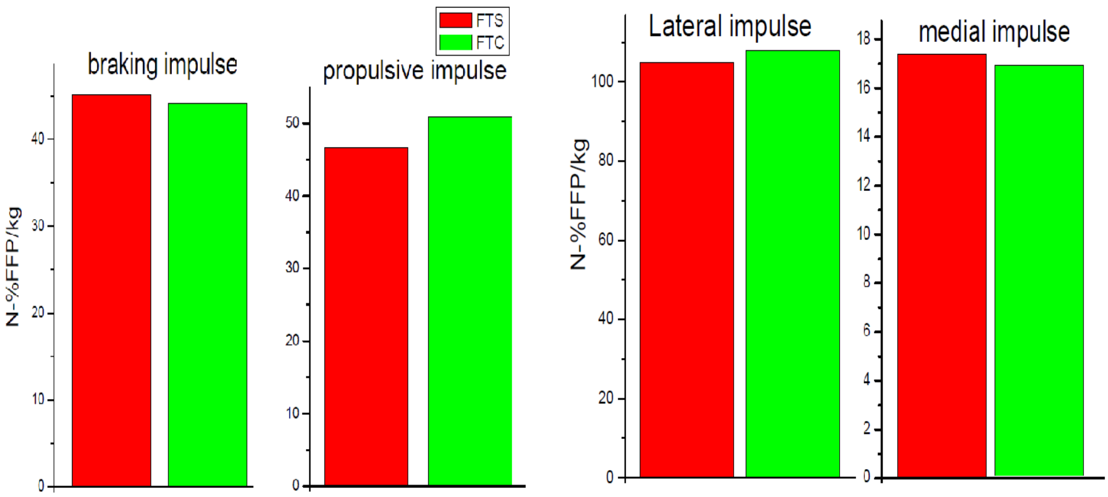

Figure 3: Bar charts depict scalar impulses that were calculated by integrating the positive and negative areas under the GRF curves.

DISCUSSION: This study compared the resolvedly horizontal GRF and GRI for two kinds of table-tennis forehand drive shots. Although there was no difference between both shots, the data provided clearer interpretations of the movements of interest. We try to figure out the mechanisms of the horizontal GRF of the lower extremities of the table tennis players. The benefits of doing so are that we can analyze the GRI and GRI through the anatomical point of view. These data can let us know how they act on the body to cause the rotation of the lower limbs. In the M-L direction, the lateral GRI of this study was the largest one. That was similar with the previous turning studies. During constant velocity circular walking, the M-L GRI is the important factor causing to shift the body towards the center of the circle (Orendurff, Segal, Berge, Flick, Spanier, & Klute, 2006). Another turning study also showed that larger lateral impulses likely contributed to the change in COM trajectory (Glaister, Burnets, Schoen, & Klute, 2008). In this study, the players tried to increase the lateral impulse to cause the trunk rotation during the 60% durations of the FFP. The magnitude and durations of the braking and propulsive impulse of this study was almost the same. In the study of straight walking, deceleration was characterized by a larger braking impulse and a reduced propulsive impulse. And acceleration was characterized by a reduced braking impulse and a larger propulsive impulse (Orendurff, et al, 2008). So during the FFP, the players decelerated their body from initial to mid-phase and then accelerated the body to perform a forehand drive shot. A drawback existed in this study was the unpresented data of the left leg. Future work should investigate the three dimensional components of GRF of both feet using rotation matrix (Zatsiorsky, 2002; Winter, 2005) to transform the GRF from the global to the anatomical coordinate system to get more details about the kinetic strategies of forehand drive. In addition, the data collected for this study will provide biomechanical references for coaches, players or shoemakers who can produce the footwear more ergonomically.

CONCLUSION: This study tried to investigate the GRF and GRI of the forehand drive shot of table tennis in a simple and clear manner. Switching the horizontal GRF to body reference system could let us get a more directly understanding of kinetic strategies of the players. During the forehand drive shot, the participants perform a larger lateral impulse to cause the trunk rotation and decelerated their body from initial to mid-phase and then accelerated the body to perform a forehand drive shot. These data discloses kinetic strategies of forehand drive shot of table tennis.

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