INTRODUCTION

Power is a determinative element in today’s tennis competition. Many tennis athletes recognized that both powerful serving and excellent volley skills are the most important weapons that could lead to victory. Tennis is a sustaining sport. An effective swing-impact process in tennis volley not only reduces the musculoskeletal loading and energy consumption but also has better performance. Most biomechanical studies about tennis volley have not been away from kinematics (Kernodle, et al., 1982; Elliott, et al., 1988; Wang, et al., 2002). Few of the kinetic studies were available in the past (Van Gheluwe and Hebbelinch, 1986; Chow, et al., 1999a). It meant that few studies have attempted in studying the biomechanical aspects of tennis volley, especially the power transfer between segments (Chow, et al., 1999b). Groppel (1984) stated that the development and transfer of angular momentum from the ground reaction force through the body segments and finally to the racket may be one of the least understood concepts in tennis. Therefore, the purpose of this study was to investigate the angular momentum of upper extremity on tennis punch and drop volley in elite tennis athletes.

METHODS

Six male elite tennis players (age: 26.5±9.4 yrs, height: 173.3±3.8 cm, weight: 67.3±11.0 kg) with right hand dominant were recruited in this study. All subjects have played tournaments for many years. They were in good physical condition and used the same tennis racket when collecting the volley motion data. Sixteen markers were attached on the selected anatomic landmark unilaterally and racket to define the coordinate system of each segment. The Expert Vision motion system with six cameras (Motion analysis Corp., Santa Rosa, CA, USA) was used to collect the tennis volley motion at sampling rate of 240 Hz. Ten trials were collected for each subject with a 3-minute rest between trials. A four-segment linkage system, including the trunk, upper arm, forearm, and hand plus racket were adopted for the present study. Each body segment was modelled as a rigid body. In order to calculate the angular momentum for each segment, the orthogonal segmental coordinate system could be determined. The angular momentum in segment coordinate system (\(H')\) is defined as the product of the principal moment of inertia (\(I\)) and angular velocity in segmental coordinate system (\(\omega'\)). The calculation of three directions moment of inertia relative to the segment centre of mass was also adapted from the previous study (McConville, 1980). The racket’s moments of inertia about three orthogonal axes (longitudinal, frontal and transverse) were computed using the pendulum method (Brody, 1985). It could be expressed as:

\[
H'_i = I_i \omega'_i, \quad H'_y = I_y \omega'_y, \quad H'_z = I_z \omega'_z
\]  

The magnitude of the three angular momentum vector was used for results presentation. It could be expressed as:

\[
H = \sqrt{H_y^2 + H_z^2 + H_z^2}
\]  

RESULTS AND DISCUSSION

The angular momentum of upper extremity and racket in forehand volley was showed in Figure 2. The patterns of angular momentum in upper arm, forearm and hand were very similar in drop volley and punch volley. The changes of all angular momentums were very small except racket in punch volley. The racket had the largest angular momentum in most of the volley motion. For the upper extremity, the upper arm contributed most of the angular momentum among all segments. In both volley strokes, upper arm angular momentum increased at early acceleration, then forearm increased at mid-acceleration. In punch volley, after mid-acceleration, forearm didn’t have any angular velocity change and its angular momentum kept the same value. In drop volley, forearm momentum started to decrease before impact. The angular momentum in punch volley was larger than drop volley in upper arm and forearm and the angular momentum in upper arm and forearm decreased in drop volley after ball impact. That was because punch volley needed stronger power than drop volley. The angular momentum in hand in drop volley increased its value just before ball impact. That matched the real drop motion.
Figure 2: Forehand volley angular momentum

Figure 3 showed the results in backhand volley. The angular momentum in upper arm and forearm declined gradually first, then increased both in punch and drop volley. However, the smallest value occurred in the mid-acceleration phase in punch volley and around ball impact in drop volley. Forearm angular momentum increased rapidly at mid-acceleration and reached the peak (0.08Kg·m²·sec⁻¹) at impact, then decreased till the end of volley. From the mid-acceleration to end of volley, upper arm angular momentum kept increasing and racket angular momentum also increased from mid-acceleration to impact (0.19.Kg·m²·sec⁻¹). The angular momentum in hand in both forehand and backhand drop volley varies little throughout the volley (particularly the backhand momentum). This will help lessen the loading of the extensor carp radialis (Chow, et al., 1999a). What has been stated above proved that hand angular momentum in both forehand and backhand drop volley tends to be stationary. That proved that in such motion such as tennis drop volley, the player has to extend the contact time between the racket and ball and increased swing power in follow-through to change the ball moment and its final speed.

SUMMARY

From this study, the larger angular momentum in punch volley may indicate that it required greater rotatory momentum to bounce back the ball than drop volley. The upper arm contributed most among all segments. The tennis player has to extend the contact time between the racket and ball and increase swing power in follow-through to change the ball moment and its final speed. Understanding of the 3D biomechanical behaviour of upper extremity during different types of tennis volley could allow tennis players and coaches to improve their performance and prevent injury. It is also helpful for the physicians and therapists in diagnosis of sports injury and clinical treatment.

REFERENCES


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