Effects of Handle Diameters and Vibration Dampener on Postures and Performance during Tennis Volley

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Abstract. *The purpose of present study was to examine the effects of ball speed, handle diameter of racquet, and vibration dampener on elbow and wrist postures, and successful hit-rate during tennis volley. Ten subjects performed 18 combinations of volley bouts at one of ball speed (i.e., 40, 55 and 75 km/h) and two statuses of vibration dampener (none and usage) with three handle diameters of racquet (33, 35 and 38 mm). Postures of elbow and wrist were recorded using the wireless capture the moment system (TEA, France). Results of MANOVA revealed a significant main effect for ball speed, handle diameter of racquet, and vibration dampener. The movements of elbow and wrist were higher while ball speed increased to high speed and applied the large handle. As expected, successful hit-rate decreased on high ball speed. In addition, an interesting result from the viewpoint of hit rate was the significant interaction between ball speed and handle diameters. The hit rate reached on top in handle diameter of 38 mm. By contrast, the hit rate decreased dramatically while ball speed increased from 40 km/h to 55 and 75 km/h. The results of the present study may provide meaningful information applicable to the design tennis racquet and training.*

Keywords: *Tennis racquet, Volley, Handle diameter, Vibration dampener*

1. INTRODUCTION

Tennis is a global sport, with participation in more than 200 countries affiliated with the International Tennis Federation. Like many other sports, playing tennis participants were at risk of injuries. A systematic search of published reports was carried out in three electric databases from 1966 on to identify relevant articles relating to tennis injuries (Pluim et al., 2006). There is a great variation in the reported incidence rate of tennis injuries. The most injuries occur in the lower extremities, followed by the upper extremities and then the truck. Sport-related injuries about the elbow occur commonly and are often managed by a wide variety of health care providers. The incidence and prevalence rates for tennis elbow were quite high, with reported incidence varying from 9% to 35% (Gruchow and Pelletier, 1979; Carroll, 1981) and prevalence varying from 14% to 41% (Priest et al., 1980). Elbow injuries are typically seen in throwing athletes but can also occur in athletic disciplines that require lifting, pushing, pulling, or transfer of force to a racquet or other piece of sporting equipment (Badia and Stennett, 2006). The chronic injuries associated with overuse can be a result from intrinsic or extrinsic mechanisms. Intrinsic mechanisms described the essentially tendonitis or associated inflammatory problems that result from a repetitive force of muscular contraction leading to microtrauma to the soft tissues involved. Extrinsic mechanisms involve external forces being applied to the elbow that cause injury over the long term. In addition, epidemiological data have shown that tennis injuries are primarily caused by overuse.

Performance in many sports is influenced to a certain extent by the equipment used. Tennis is one of those sports and the key pieces of equipment in performance are the

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racket, ball, surface and shoe (Miller, 2006). Modern rackets are composed mainly of graphite, strips of which are wrapped around a racket mould and left to harden. The most obvious of racket design was an increase in head size, which was possible because of the greater strength of the new materials. So the International Tennis Federation responded by limiting racket size to 29 × 12.5 inches (73.7 × 31.8 cm). On the other hand, racket mass has decrease from about 400 g to 250g. This decrease in mass has the important spin off that players are able to swing the racquet faster, which generates higher impact speeds, resulting in faster ball speeds. This decrease in mass has the important spin off that players are able to swing the racquet faster, which generates higher impact speeds, resulting in faster ball speeds. In addition, vibration is produced when the ball impacts the racket. The amount of vibration is dependent on the racket stiffness and impact location. Many players use vibration damping devices to reduce discomfort for off node impacts. Brody (1989) has shown that dampeners attached to the strings are effective in damping out string vibration, but have little effect on the racket frame.

Modern rackets have facilitated a change in playing style from one technique to one characterized by power and spin. The combination of the increased stiffness of modern rackets and the tendency for tennis balls to have become harder has led to an increased shock transmission from the racket to the player, which is probably a major contributor to tennis elbow (Miller, 2006). Thus, the purpose of present study was to examine the effects of handle diameter of racquet, vibration dampener and ball velocity on volley postures, and hit-rate.

2. METHODS

2.1 Participants

The study was approved by the Research Ethics Committee of the researcher’s institution. Ten male students that had undergone advance training (as tennis team in university) participated in the experiments after providing informed consents with respect to the investigative procedures. The mean age was 22.6 years, mean stature 174.7 cm, and mean body mass 60.7 kg. In addition, mean hand length, hand width and hand depth were 19 cm, 10 cm and 3.5 cm respectively. All subjects were healthy and reported no musculoskeletal problems or cardiovascular diseases which might be detrimental to physical performance. In addition, all recruits were instructed to avoid vigorous physical activity and alcohol consumption during the 12 hours prior to the experiment.

2.2 Apparatus and Materials

Present study applied the graphite racket (Wilson, Pro Staff) with 323 g, replacement grips (Kawasaki, thickness: 0.82mm), custom damp (Babolast), tennis balls (Wilson Big Giant) and tennis ball machine (Master Sports, Millennium II). In addition, the miniature joint angle sensor (S720, Measurand Inc., Canada) and shape sensor (S700) were mounted on the neutral axis of wrist and elbow respectively (Figure 1). Thus, wrist angles and flexion angles of elbow were measured by CAPTIV L3000 Analysis Software (TEA, France). The synchronous acquisition of video together with measurements was captured by digital camera (Sony DCR-TRV40).

Figure 1: Posture measured by joint angle sensor.

2.3 Experimental Procedures

Before commencement of the actual experiment, participants were given an opportunity to warm-up and practice tennis ball machine and asked to perform known all experimental tasks until they were able to produce steady manipulation. Each participant stood in front of the net about 1.5m to prepare volleying the ball from machine and hit the ball on target area (1.3×0.87 m). A total of 18 trials were performed at three ball speed (40, 55 and 75 km/h), three handle diameters (33, 35 and 38 mm), and dampener attached or without dampener (Figure 2). The order of these trials was randomly assigned for each subject. In addition, each trial volleyed for at least 25 times or more (if required) until measurements stabilized. A minimum rest period of 20 min (more if required) was provided between trials until baseline physiological indices were restored. During the rest periods, participants were asked to stay seated, relax and remain silent. If baseline measurements could not be achieved after a rest period, the experimental session was resumed the next day.

Figure 2: Volley experiment in court.

2.4. Data Analysis

A randomized complete block design (blocks as individual subjects) with three within-subject factors (handle diameters, ball speed and dampeners status) was used for this study. The wrist angles and flexion angles of elbow were measured by CAPTIV L3000 Analysis Software. All trial data files were exported in Microsoft Excel format, with the mean values for dependent variables then calculated over the final 10 times of each trial, by which time observed variables were deemed to have achieved a steady state for in each participant. In addition, the mean successful rates for each trial were calculated. Further, Multivariate analysis of variance (MANOVA) was utilized to identify significant differences between conditions for dependent variables. Statistical significance was set at a probability level of 0.05.

3. RESULTS

The mean elbow angles and wrist angles on hit, low level, high level and movement range values during volley are presented in Table 1 and Table 2, respectively. Multivariate analysis of variance (MANOVA) was conducted for the dependent variables. Further results have been presented as follows.

3.1. Effect of ball speed

Results of MANOVA revealed a significant main effect for ball speed (Pillai's trace = 0.824, F(22, 296)= 9.43, $p < 0.001$). Univariate F tests show significantly differences between ball speed in elbow angles of low level, high level and movement range. There was higher movement range when ball speed was increased from 40, 55 to 75 km/h. In addition, wrist angles were the same responses on the highest ball speed. As expected, the hit rate was decreased from 39.8%, 29.4%, 12.6% as increased ball speed from 40. 55, 75 km/h, respectively.

3.2. Effect of handle diameters

Univariate F tests show significantly differences between handle diameters in elbow angles of high level. There was lower elbow extension in handle diameter of 33 mm. In addition, wrist angles were the higher movement in handle diameter of 33 mm. For hit rate, there was not significant difference between handle diameters.

3.3. Effect of vibration dampener

Results of analysis showed that there was only significant difference in hit rate between with vibration dampener and without vibration dampener. The higher hit rate was found with vibration dampener during volley.

3.4. Interaction between ball speed and handle diameters

An interesting result from the viewpoint of hit rate was the significant interaction between ball speed and handle diameters (F(4, 157) = 2.374.88, $p < 0.05$; Figure 3). The hit rate reached on top in handle diameter of 38 mm. By contrast, the hit rate decreased dramatically while ball speed increased from 40 km/h to 55 and 75 km/h. Middle handle diameter maintained the better hit rate on ball speed of 40 and 55 km/h. The hit rate reached on lower level in all handle diameters while ball speed increased to 75 km/h.

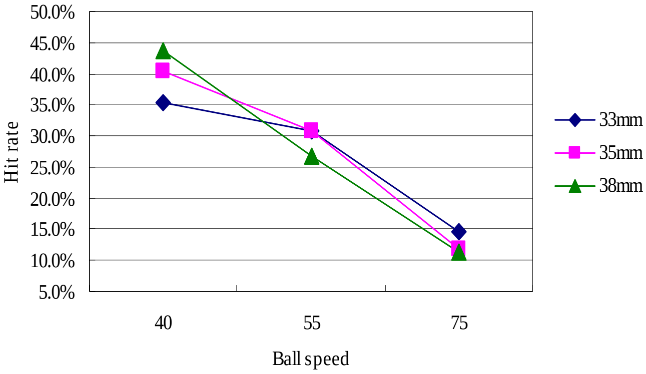

Figure 3: Interaction between ball speed and handle diameters on hit rate

4. DISSCUSION AND CONCLUSION

Present study was applied the wireless capture the moment system to examine the effects of handle diameter of racquet, vibration dampener and ball speed on volley postures, and successful hit-rate. Results of MANOVA revealed a significant main effect for ball speed, handle diameter of racquet, vibration dampener. For elbow and wrist postures, the movements of elbow and wrist postures were increase in high ball speed and larger handle of racquet. For vibration dampener effect, these were not significant difference in low and middle ball speed. However, the mean extension angle of wrist was decreased significantly in high ball speed (i.e. 75 km/h). The results of the present study may provide meaningful information applicable to the design tennis racquet and training.

Perform proper warm-up and stretches prior to and after play. It is important to strengthen and condition the muscle for the high demand of the sport. Nirschl (1990) described the correct grip size about measuring the length from the detail tip of the small finger to the proximal palmar crease. In addition, a handle that is too small increase the load on the elbow and causes muscle fatigue. By contrast, a handle that is too large limits the wrist snap while serving and causes difficulty when changing grips throughout play. The second issue is the proper strokes. Hit the ball in the sweet spot, the center of the racquet for ideal contact. Keep the elbow close to the body during ball contact to decrease the torque on the body. On performance the backhand stroke, avoid flexing the wrist on impact and with the serve avoid aggressively pronating the forearm. Avoid maintaining a sustained grip, only tighten grip on impact. For the equipment, add a cushioned grip to prevent slippage of the racquet. A medium flexible frame (95-110 square inches) in graphite to minimize vibration and shock throughout the arm is recommended. Change and absorb the sound of the impact vibration but do not minimize shock.

Tennis has often been described as a game of continual emergencies because with every shot the opponent hits, a ball can have a different velocity, a different type and rate of spin, be placed in many different parts of the court (Groppel, 1986; Kovacs, 2006). Also, there is still healthy debate over tennis players and what methods of training are most beneficial and efficient both from a performance enhancement perspective and for preventing injuries.

Table 1: Mean elbow angles on hit, low and high level during volley

	Hit	Low	High	Movement range
Ball speed (km/h)				
40	131.8	125.5***	171.3*	45.7***
55	132.2	123.7	169.1	45.3
75	132.4	116.8	169.5	52.7
Handle diameters (mm)				
33	131.6	122.1	168.7*	46.6
35	132.4	122.4	170.6	48.2
38	132.4	121.6	170.6	48.9
Vibration dampener				
with	131.8	121.8	170.4	48.5
without	132.5	122.2	169.5	47.4

* $p < 0.05$; ** $p< 0.01$; *** $p < 0.001$

Table 2: Mean wrist angles on hit, low and high level during volley

	Hit	Low	High	Movement range
Ball speed (km/h)				
40	54.8	35.9***	48.1**	12.2***
55	56.6	36.1	51.4	15.4
75	54.7	30.6	50.7	20.3
Handle diameters (mm)				
33	54.4	33.3	47.7***	14.7**
35	54.6	34.5	49.7	15.3
38	57.1	34.9	52.8	17.9
Vibration dampener				
with	55.2	34.3	50.1	15.9
without	55.6	34.1	50.1	16.1

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Table 3: Effect of ball speed, handle diameter of racquet, and vibration dampener on mean successful hit-rate

	Successful hit rate (%)
Ball speed (km/h)	
40	39.8 ***
55	29.4
75	12.6
Handle diameters (mm)	
33	26.9
35	27.6
38	27.3
Vibration dampener	
with	29.0 *
without	25.5

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