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Experimental study on the effects of the larger tennis balls on the comfort of the wrist and the elbow

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***ABSTRACT*:** This study was conducted because a recent rule change by the ITF has allowed larger balls (7 ~ 8 % increase in diameter while keeping the same mass) to be used in tournaments. The intension of introducing the larger ball is to slow down more during the flight through the air thus reducing the dominance of the ' big-servers' on fast surfaces such as grass. This paper investigates the effect of the larger ball on the impact shock vibrations of the arm of a tennis player. The accelerations at the player's wrist joint and the racket handle were measured during the forehand groundstroke. The accelerations at the player's elbow joint and the racket handle were also measured during the service stroke. The results showed that the waveforms of the normal ball and larger ball are very similar when a male tournament player hits flat forehand drive. With the measured accelerations at the player's elbow joint and the racket handle when a male tournament player hits service near the center of the racket face, the waveforms of the normal ball and larger ball were also very similar. Since the drag force of the larger ball should be greater than that of the normal ball, the velocity of a larger ball should be slower. Thus, the impact shock vibrations of the arm should be reduced.

INTRODUCTION

The International Tennis Federation (ITF) has approved on 1st January 2000 a two-year experimental program in which two new types of tennis ball will be permitted to be used for the purpose of detailed evaluation and development. The new types of balls are designed to have specifications which will result in different performance characteristics derived from their differing dynamic and aerodynamic properties. It is intended that the two new ball types, in addition to the existing ball types, be introduced and developed to improve the appeal and enjoyment of tennis at all levels for players and spectators alike (ITF, 2000).

This study was conducted because a recent rule change by the ITF has allowed larger balls to be used in tournaments. The intension of the larger ball is to slow down more during the flight through the air thus reducing the dominance of the ' big-servers' on fast surfaces such as grass. The coefficient of restitution was studied for two different types of oversized tennis balls for normal impacts on a rigidly clamped racket by Goodwill and Haake (2000).

This paper investigates experimentally the effects of larger balls (7 ~ 8 % increase in diameter while keeping the same mass and same rule) on the impact shock vibrations of the arm of a tennis player (Kawazoe et al., 1992, 1993, 1994, 1997, 2000a, 2000b, 2001). Figure 1 demonstrates the three types of balls where Type 3 is a larger ball and Type 2 is an existing normal ball.

Type 3 (larger)   Type 2 (existing)   Type 1

Fig.1 Three types of balls (the masses are the same).

OUTLINE OF THE EXPERIMENTS

The acceleration of the shock vibrations at the player's wrist joint and at the racket handle was measured when a player hits flat forehand drive. The accelerations at the

Fig.2 Situation of hitting test.

player's elbow joint and the racket handle were also measured when a player strikes a ball during service stroke. The location of the accelerometer on the racket handle is 210 mm from the grip end. The waveforms when struck at the off-center (top side) and those at the center of a racket face were recorded during forehand stroke, while the waveforms when struck near the center were recorded during the service stroke.

Although we tested 3 types of balls, we will report here the comparison between the larger ball and the conventional normal ball. Two rackets named Prince SG were used in this test, and each racket was strung at 45 lbs and 65 lbs respectively. The mass of strung racket was about 338 [g], total length 685 [mm], and the balance (center of gravity from grip end) was about 327 [mm] as shown in Table 1. The sign I_{GY} denotes the moment of inertia about the center of mass, the sign I_{GR} the moment of inertia about the grip portion 70 mm from the grip end, the sign I_{GX} the moment of inertia about the longitudinal axis of the racket head.

Figure 2 shows the situation of the test. Figure 3 indicates the location of accelerometers at the wrist joint and the racket handle in the forehand groundstroke. Figure 4 also indicates the location of accelerometers at the elbow joint and the racket handle in the service stroke. Five trials are recorded per each test condition.

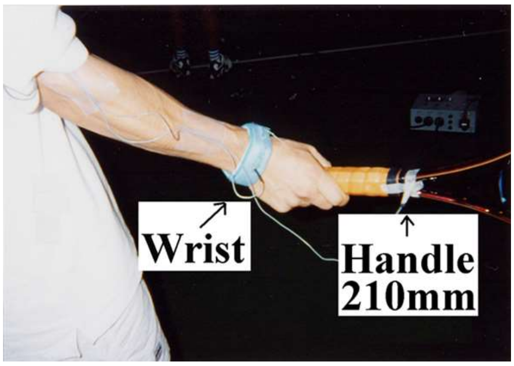

Fig.3 Location of accelerometers at the wrist joint and the racket handle for the forehand ground stroke.

Fig.4 Location of accelerometers at the elbow joint and the racket handle for the service stroke.

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Table 1 Racket specifications and main physical properties

Rackets	prince SG		
Tention	45lb	55lb	65lb
Total length	687 mm	685 mm	688 mm
Mass	336.5 g	338.0 g	338.5 g
Center of gravity	329 mm	327 mm	330 mm
Face area	694 cm^2		
Moment of inertia I_{GY} about Y axis	15.0 gm^2		
Moment of inertia about grip (70mm)	37.3 gm^2		
Period about Y axis	1.317 s		
X axis			
Period about X axis	1.055 s		
Moment of inertia I_{GX} about X axis	0.935 gm^2		

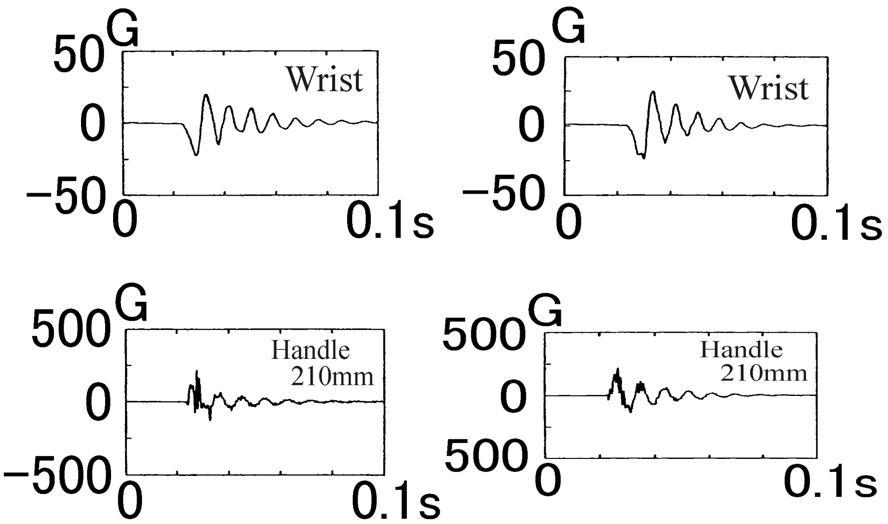
EXPERIMENTAL RESULTS FOR THE WRIST JOINT DURING A FOREHAND DRIVE

Fig. 5and Fig.6 show the measured accelerations at the player's wrist joint and the racket handle when a male tournament player hits flat forehand drive. The racket is strung at 45 lbs. Figure 5 shows comparison between the normal ball and the larger ball in terms of the measured shock vibrations at the wrist joint and the racket handle 210 mm from the grip end when struck at the off-center (top side) of the racket face. Fig. 6 shows a comparison when struck at the center of the racket face. The waveforms of the normal ball and larger ball are almost similar.

Fig. 7 and Fig.8 show the results when the racket strung at 65 lbs is used. Fig. 7 shows the comparison between the normal ball and the larger ball in terms of the measured shock vibrations at the wrist joint and the racket handle 210 mm from the grip end when struck at the off-center (top side) of the racket face. Fig. 8 shows the comparison when struck at the center of the racket face. The waveforms of the normal ball and larger ball are almost similar.

EXPERIMENTAL RESULTS FOR THE ELBOW JOINT DURING A SERVICE STROKE

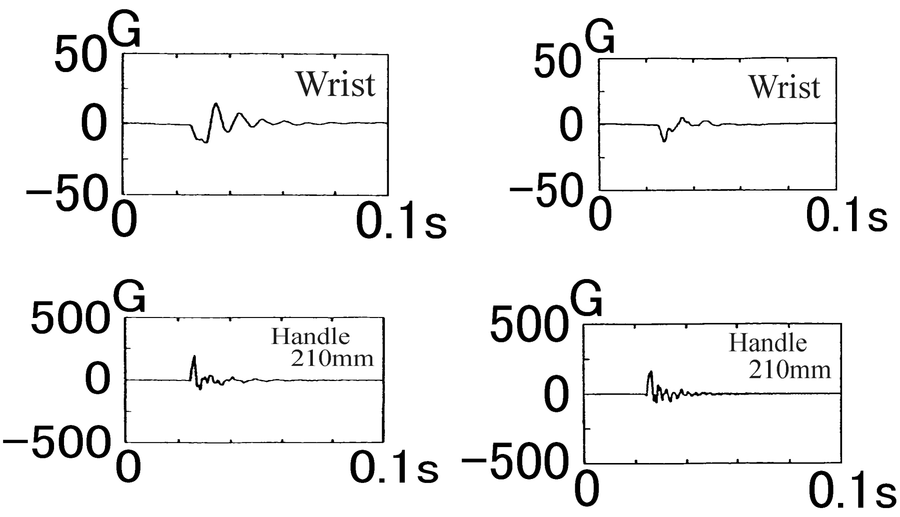
Fig. 9 and Fig.10 show the measured accelerations at the player's elbow joint and the racket handle when a male tournament player hits service stroke at the center of the racket face. Fig. 9 shows the comparison between the normal ball and the larger ball when struck service at the center of the racket face. The racket strung at 45 lbs was used. Fig. 10 shows the comparison between the normal ball and the larger ball when the racket strung at 65 lbs was used. The waveforms of the normal ball and larger ball are almost the same.



(a) Normal ball
(Impact vel.: 21±1 m/s)

(b) Larger Ball
(Impact vel.: 19±1 m/s)

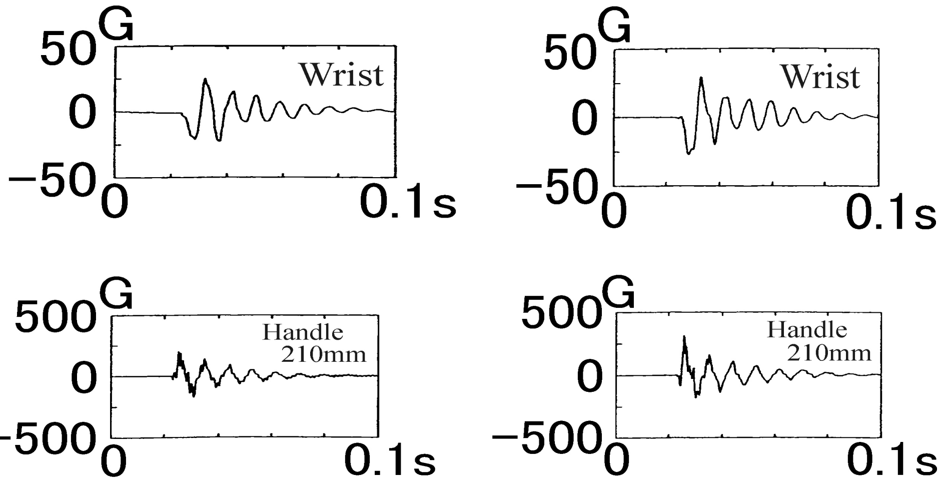
Fig.5 Measured shock vibrations at the wrist and the racket handle (210 mm from grip end) when struck flat forehand drive at the off-center (top side) of racket face strung at 45 lbs. The impact velocity here from a high-speed video is the velocity of a racket head tip when a tester hits a ball dropped from the air and bounces on the ground.



(a) Normal ball
(Impact vel.: 23±1 m/s)

(b) Larger ball
(Impact vel.: 20±1 m/s)

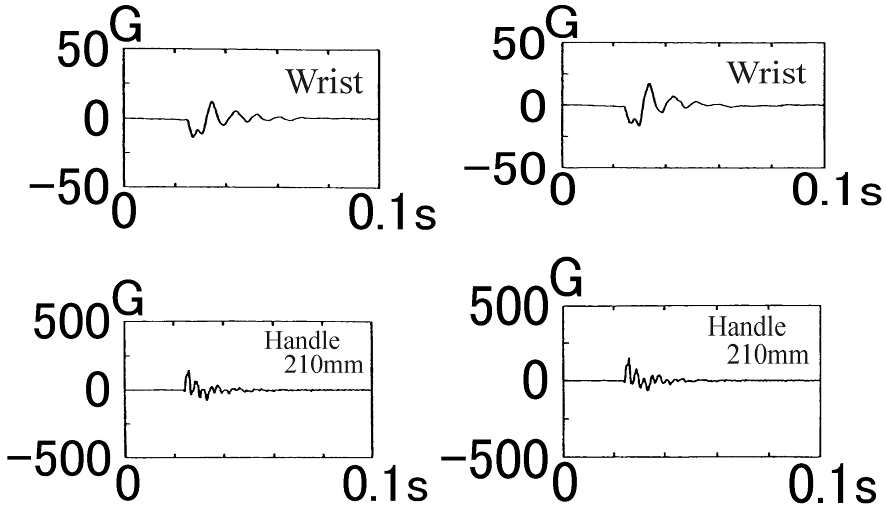
Fig.6 Measured shock vibrations at the wrist and the racket handle (210 mm from grip end) when struck flat forehand drive at the center of racket face strung at 45 lbs.



(a)Normal Ball
(Impact vel.: 21±1m/s)

(b) Larger Ball
(Impact vel.: 21±1 m/s)

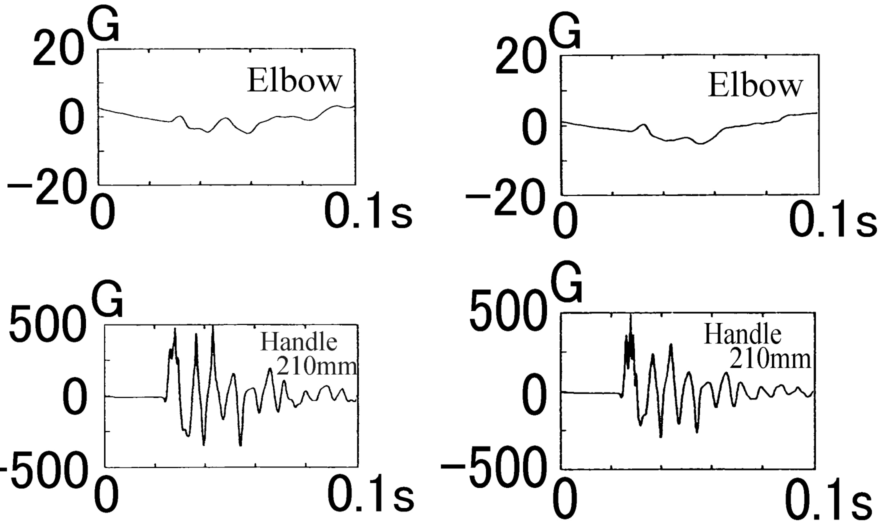
Fig.7 Measured shock vibrations at the wrist joint and the racket handle (210 mm from grip end) when struck flat forehand drive at the off-center (Top side) of racket face strung at 65 lbs.



(a) Normal ball
(Impact vel.: 18±1 m/s)

(b) Larger ball
(Impact vel.: 25±1 m/s)

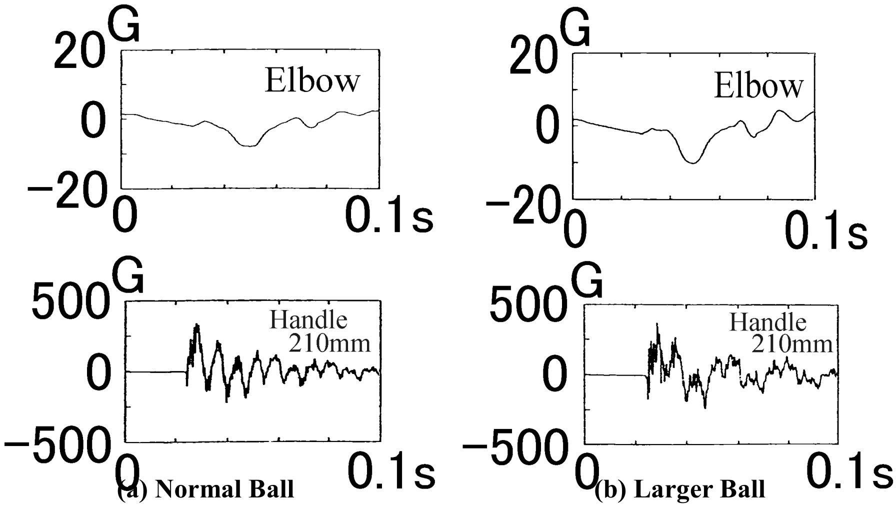
Fig.8 Measured shock vibrations at the wrist joint and the racket handle (210 mm from grip end) when struck flat forehand drive at the center of racket face strung at 65 lbs.



(a) Normal Ball
(Impact vel.: 30±1 m/s)

(b) Larger Ball
(Impact vel.: 28±1 m/s)

Fig.9 Measured shock vibrations at the elbow joint and the racket handle (210 mm from grip end) when struck service at the center of racket face strung at 45 lbs. The impact velocity here from a high-speed video is the velocity of a racket head tip when a tester hits the ball.



(a) Normal Ball
(Impact vel.: 32±1 m/s)

(b) Larger Ball
(Impact vel.: 29±1 m/s)

Fig.10 Measured shock vibrations at the elbow joint and the racket handle (210 mm from grip end) when struck service at the center of racket face strung at 65 lbs.

CONCLUSIONS

The results showed that the waveforms of the normal ball and larger ball are almost the same when a male tournament player hits flat forehand drive. The measured accelerations at the player's elbow joint and the racket handle when a male tournament player hits service stroke at the center of the racket face show that the waveforms of the normal ball and larger ball are almost the same. Owing to limited space the reasons why they are almost the same are described in the separate paper (Kawazoe 2002). Since the drag force of the larger ball should be larger than that of the normal ball, the velocity of a larger ball should be slower. Thus, the impact shock vibrations of the arm should be reduced. The computer simulation of the effect of the larger ball on the shock vibrations of the arm will be separately reported in the near future.

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