Prediction of the Effect of Larger Ball on the Factors Associated with Impact and the Shock Vibrations at the Wrist Joint in the Forehand Drive

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1. Racket Specification

Fig.1 shows the size of normal ball and larger ball, and the mass of both balls are about 58 g. Two rackets (Prince SG) were used in this test, and each racket was strung at 45 lbs and 65 lbs. The mass of strung racket was 338[g], total length 685[mm], racket face area 694 cm2, and the balance (center of gravity from grip end) 327[mm], moment of inertia 15.0 gm2 about the center of gravity, moment of inertia 37.3 gm2 about grip portion 70 mm from grip end, moment of inertia 0.935 gm2 about longitudinal axis.

Although we tested 3 types of balls, we report the comparison between the larger ball and the conventional normal ball.

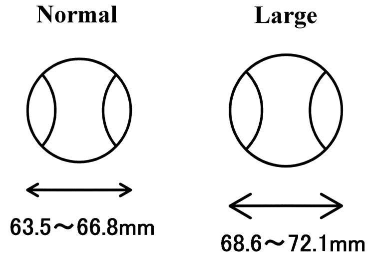


Fig.1 Normal ball and larger ball

2. Nonlinear restoring force characteristics and energy loss of ball and strings.

Figure 2 shows the test for obtaining the applied force-deformation curves schematically, where the ball was deformed between two flat surfaces as shown in (a) and the ball plus strings were deformed with a racket head clamped as shown in (b). In this work, it was assumed that the deformation of the ball versus applied force with the large ball is proportional to the diameter of the ball, which means the deformation of the larger ball is 8 % larger than that of conventional normal ball.

Furthermore, the measured coefficient of restitution e_{BG} , when a ball strikes the strings with a racket head clamped, can be regarded as the energy loss of the ball and strings due to the impact. It was assumed in this work that there is no difference in the coefficient of restitution e_{BG} between the larger ball and the normal ball.

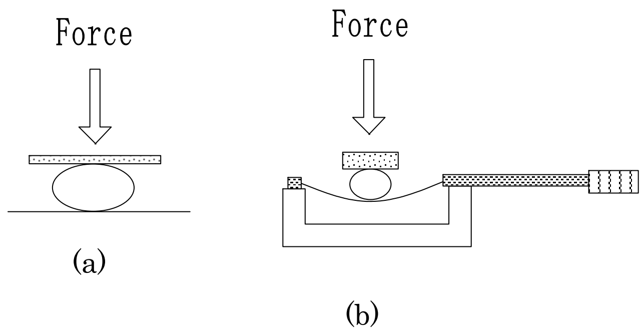


Fig.2 Measurement of restoring force characteristics

3. Predicted factors associated with impact

Figure 3 shows the reduced mass of the racket and the racket-arm system at the impact locations on the string face. The equivalent mass of 1.0 [kgf] is added at the grip from 70 mm from the grip end. The effect of the mass of arm is small except at the near off-center.

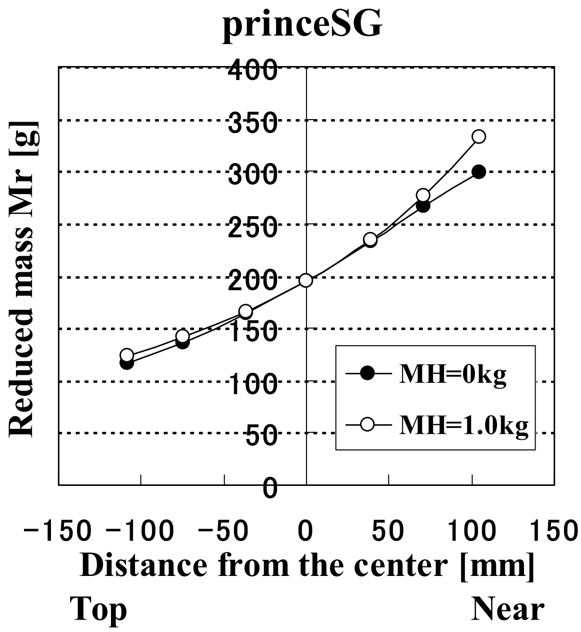


Fig.3 Reduced mass of the racket arm system

Figure 4, Fig.5, Fig.6, and Fig.7 are the predicted contact time, the maximum impact force, the deformation of the strings, and the deformation of the ball, respectively, against impact velocity at the center on the string face.

The contact time of the larger ball is slightly longer and the impact force is slightly smaller. Accordingly there is no big difference in the deformation of the string and the ball between the larger ball and the normal ball.

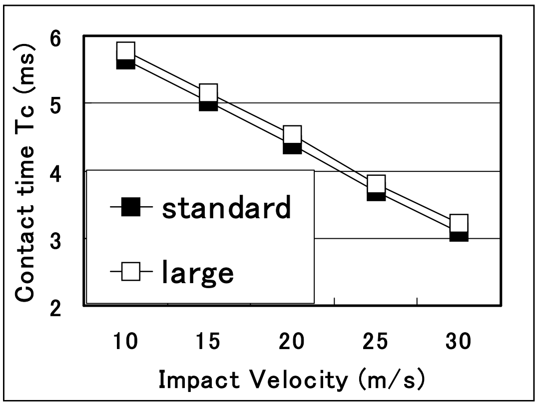


Fig.4 Predicted contact times against impact velocity at the center on the string face (45 lbs).

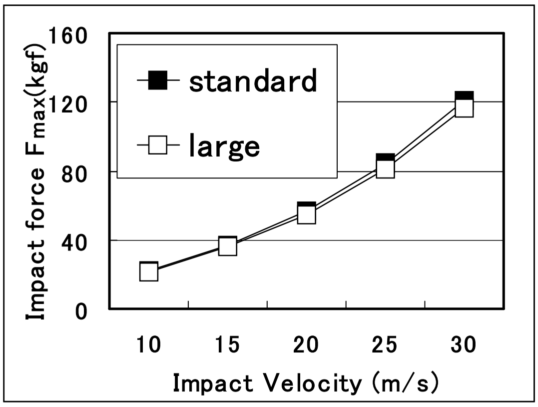


Fig.5 Predicted impact force against impact velocity at the center on the string face (45 lbs).

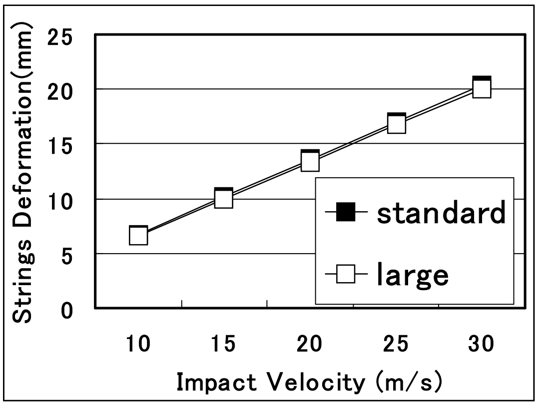


Fig.6 Predicted string deformation against impact velocity at the center on the string face (45 lbs).

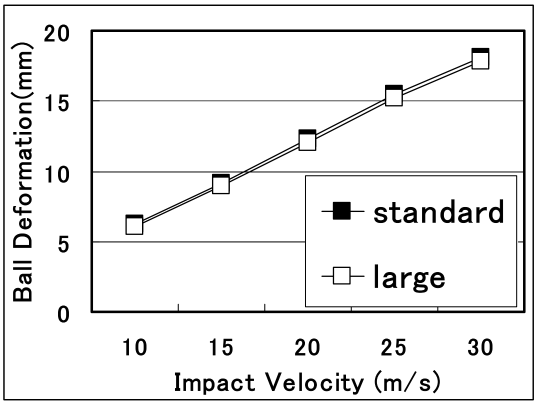


Fig.7 Predicted ball deformation against impact velocity at the center on the string face (45 lbs).

4. Predicted rebound power of the racket

Figure 8 shows the examples of the predicted post-impact ball velocity V_B at each hitting location on the racket face (pre-impact racket head velocity V_{Bo}= 10 m/s, shoulder torque N_s =56.9 Nm). There is no difference between the larger ball and the normal ball. Since the drag force of larger ball should be larger than that of normal ball, the velocity of a larger ball should be slower.

5. Prediction of the impact force and contact time at the groundstroke experiment

Figure 9 and Fig.10 show the comparison of the predicted impact force and contact time between the larger ball and the normal ball when a player hit flat forehand drive. They also show the comparison between the racket strung at 45 lbs (a) and that of 65 lbs (b). According to the high speed video analysis, the impact velocity between the racket and the ball was 25 m/s in the experiment. The impact forces on the string face of the larger ball are slightly smaller than those of normal ball, and the contact times of the larger ball are slightly longer than those of the normal ball.

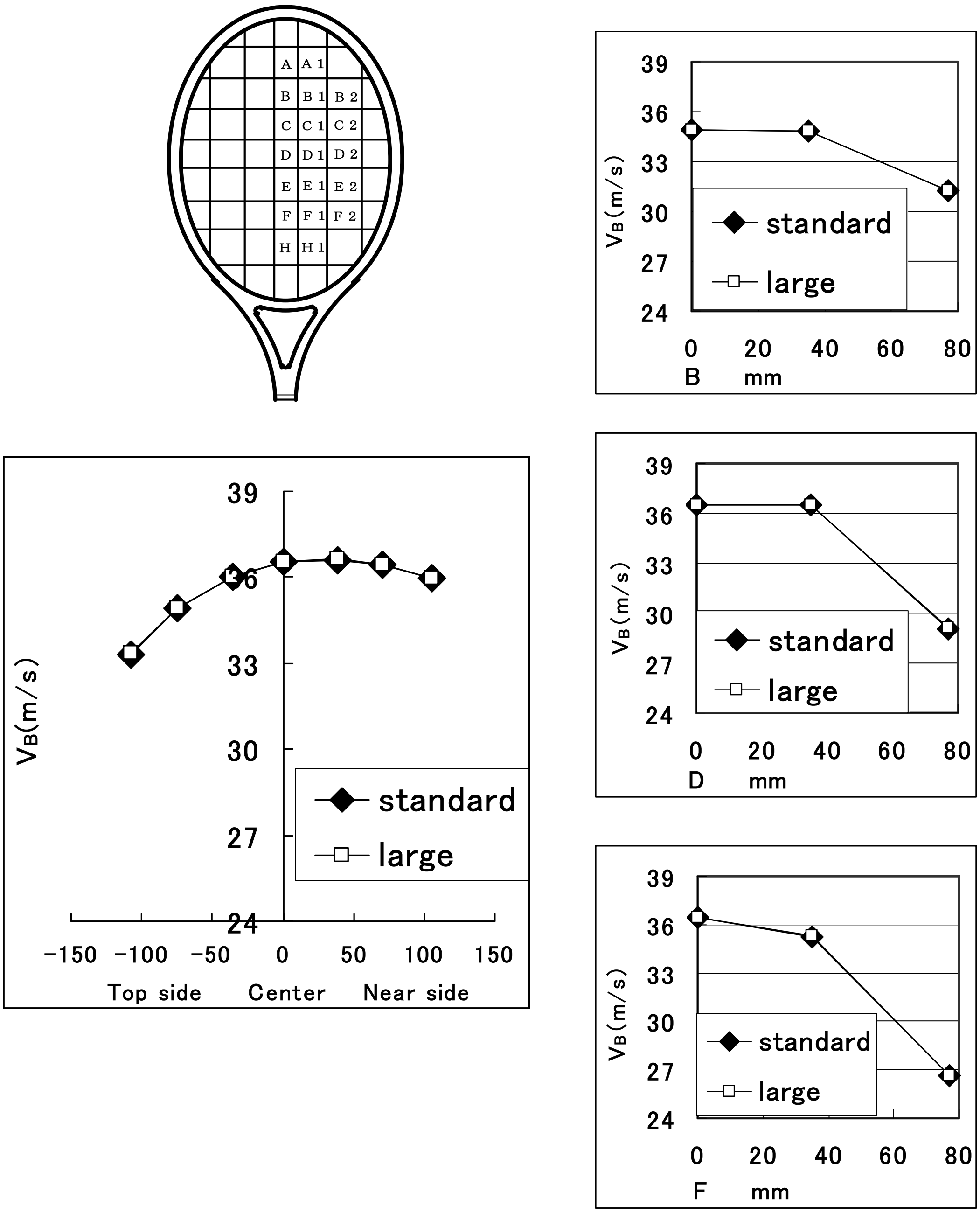
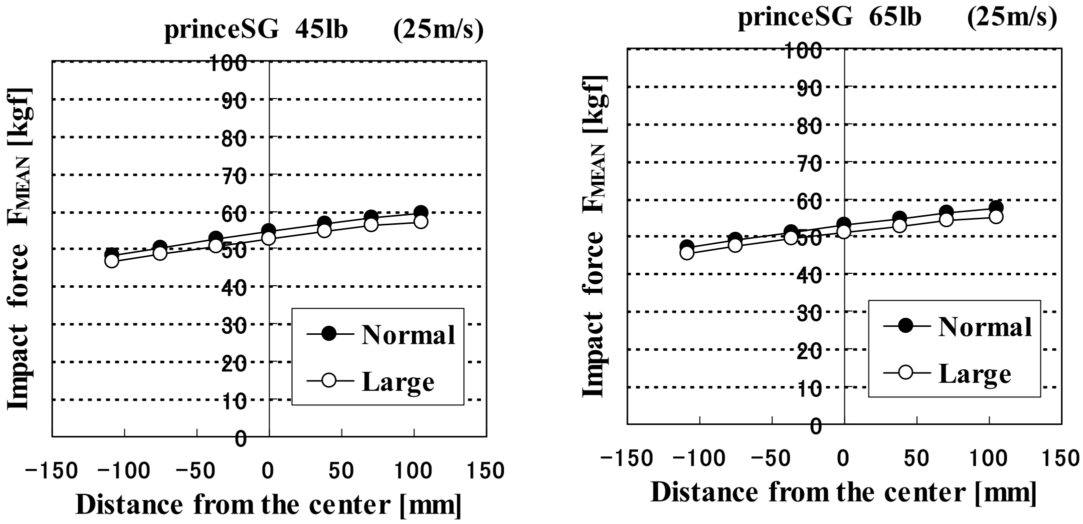
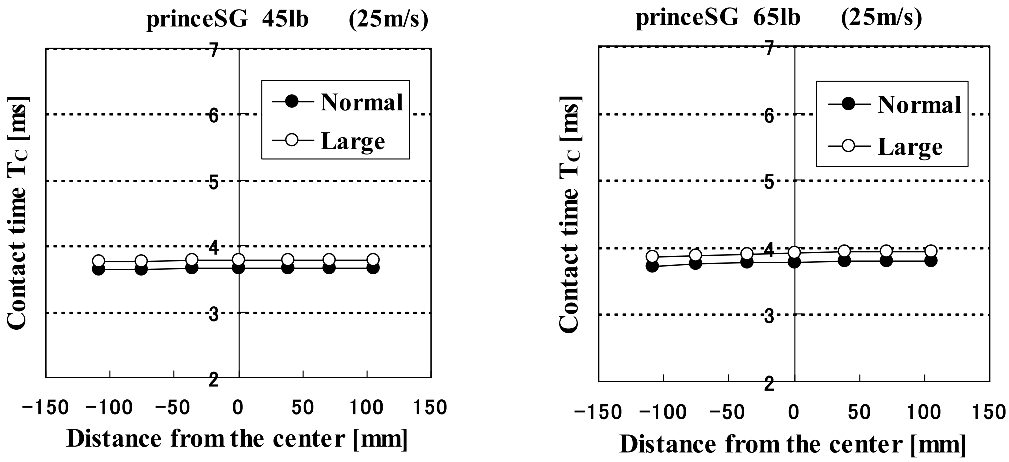


Fig. 8 Examples of the predicted post-impact ball velocity V_B at each hitting location on the racket face (pre-impact racket head velocity V_{Bo}= 10 m/s, shoulder torque N_s =56.9 Nm).



(a) 45 lbs (b) 65 lbs

Fig.9 Comparison of predicted impact force (impact velocity: 25 m/s)

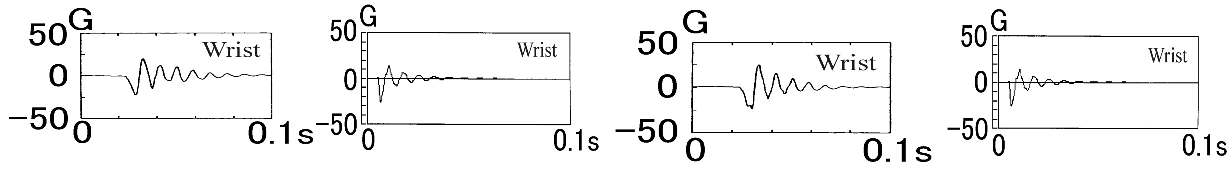


(a) 45 lbs (b) 65 lbs

Fig.10 Comparison of predicted contact time (impact velocity: 25 m/s)

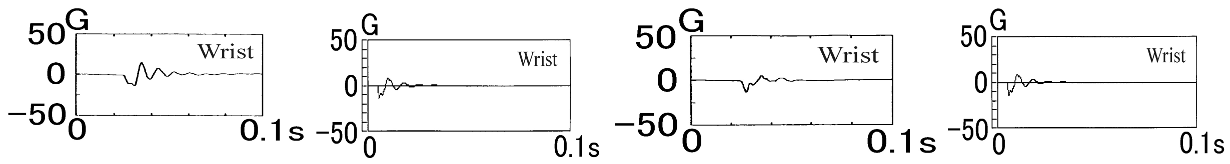
6. Predicted shock vibrations at the wrist joint and the measured ones with the larger ball and the normal ball in the groundstroke

Figure 11 shows the comparison between the predicted shock vibrations at the wrist joint and the measured ones with (a) the normal ball and (b) the larger ball in the off-center impact and center impact during the groundstroke. Impact velocity is 25 m/s and the racket is strung at 45 lbs. Figure 12 shows the results when the racket strung at 65 lbs were used.



Measured Predicted
(a) Normal ball, Off-center (Top) hitting

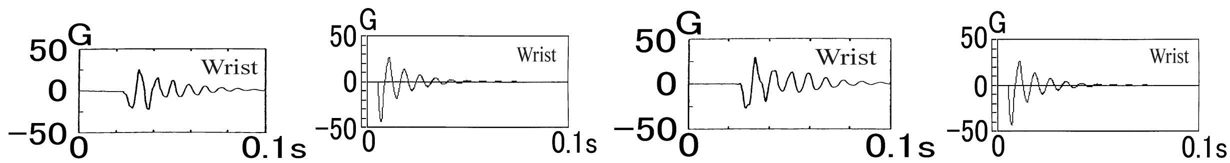
Measured Predicted
(b) Larger ball, Off-center (Top) hitting



Measured Predicted
(a) Normal ball, Center hitting

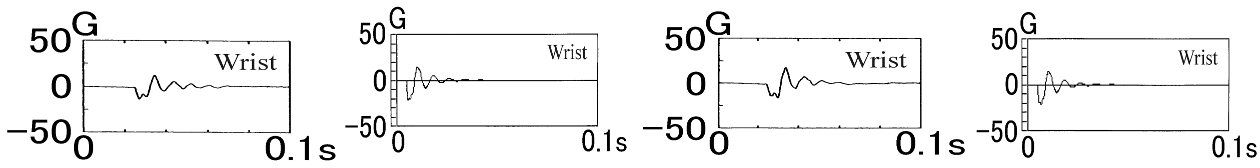
Measured Predicted
(b) Larger ball, Center hitting

Fig.11 Predicted shock vibrations at the wrist joint and the measured ones with (a) the normal ball and (b) the larger ball in the off-center impact and the center impact during the groundstroke. Impact velocity is 25 m/s and the racket is strung at 45 lbs.



Measured Predicted
(a) Normal ball, Off-center (Top) hitting

Measured Predicted
(b) Larger ball, Off-center (Top) hitting



Measured Predicted
(a) Normal ball, Center hitting

Measured Predicted
(b) Larger ball, Center hitting

Fig.12 Predicted shock vibrations at the wrist joint and the measured ones with (a) the normal ball and (b) the larger ball in the off-center impact and the center impact during the groundstroke. Impact velocity is 25 m/s and the racket is strung at 65 lbs.

Since the drag force of larger ball should be larger than that of normal ball, the shock vibrations of a larger ball should be smaller.
Figure 13 shows the peak value between the maximum and minimum of acceleration waveform at the grip of freely suspended racket. Figure 14 shows the shock vibrations peak values at the grip of the larger ball compared with the normal ball against the location of string face of the freely suspended racket . The shock vibrations at the grip of the larger ball is almost the same as those of normal ball.

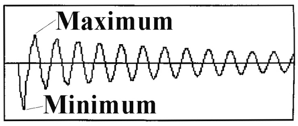
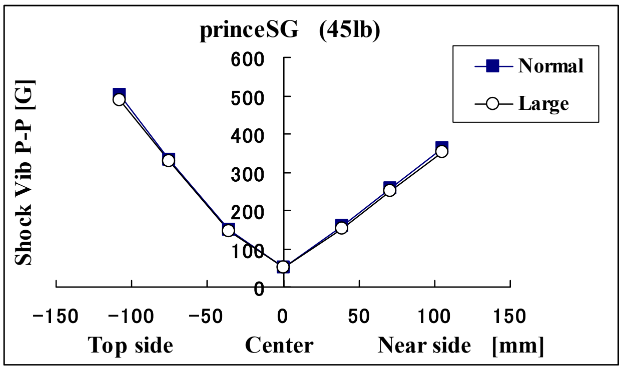
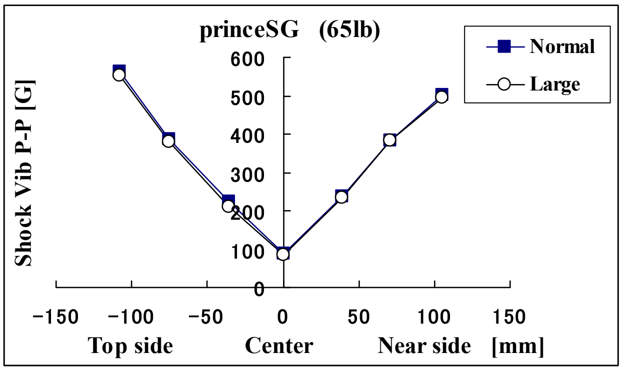


Fig.13 Peak value of shock vibrations



(a) Prince SG (45lb)



(b) Prince SG (65lb)

Fig.14 Shock vibrations Peak values of larger ball compared with the normal ball against the location of string face (impact velocity: 30 m/s).

7. CONCLUSIONS

(1) The simulated results have fairly agreed with the experimental results.
(2) The waveforms of the shock vibrations at the wrist joint when using the larger ball is almost the same as those when using the normal ball independent of the string tensions.

Since the drag force of larger ball should be larger than that of normal ball, the shock vibrations of a larger ball should be smaller.

(3) The contact time of the larger ball is slightly longer and the impact force is slightly smaller. Accordingly there is no big difference in the deformation of the string and the ball between the larger ball and the normal ball.

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