Speed and spin characteristics of the 40mm table tennis ball

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Abstract The ball size for table tennis has been changed the ITTF (The International Table Tennis Federation). The new ball has been used in the official game since October 2000. According to the new rules, the diameter of the ball is enlarged from 38mm to 40mm, and the weight of the ball is increased from 2.5g to 2.7g. It is estimated that there will be some changes in the playing style and the game tactics because of the new ball. The purpose of this study was to compare the hitting properties of the new ball (40mm ball) with the old ball (38mm ball) in order to show the influence on players. The reduce ratios of ball speed between the shoot out point to receiving point were calculated by using a ball shoot machine and a speed measurement system. Initial velocities and ball spins were calculated by using a golf-swing robot and a high-speed video camera system. The robot hit the balls with different speeds and angles by a racket fitted to the robot arm. An all-round wooden bat covered with a reverse-soft rubber was used. The Average values of rally time for the two kinds of balls were measured, and the three kinds of basic shots, drive, chop and serve, were made in the rallies by skilled payers. The following results were obtained;

(1) The initial velocity of the 40mm ball was 1-2 %, and the ball spin was 5-20 %less than the 38mm ball.

(2) No difference of the deceleration of speed between the 40mm ball and the 38mm ball was observed.

(3) The average rally times of the 40mm ball were 2-4 % longer than the 38mm ball for drive and chop shots.

(*Key words*: 40mm ball, speed, spin, rally time, declaration)

1 Introduction

Generally a table tennis ball is excellent at both bounce and speed, so the ball speed of top players can reach to almost 35 m/s. Also, because of the characteristic of the "smallness" and "lightness" of the ball, the spin can reach to 151 r/s. In old table tennis rules, the ball was 38mm in diameter and 2.5 g (38mm ball) in weight. However, the ITTF decided to revise the rule to introduce a larger

ball from 2000. According to the new rule, the standard ball is now 40mm in diameter and 2.7 g. The ratios of increase of the size and weight are 5.26 % and 8.00 % respectively.

It is supposed that because of the decrease of ball speed and spin, the 40mm ball becomes more visible, and it becomes easier to keep the ball in play. What is more, the deceleration of the ball would have an influence on the delicate skill of table tennis. Up to now, only a few test results have been reported on the speed and spin of the 40mm ball. In Zhang's test (2000), the 40mm ball speed was 13 % less and ball spin was 21 % slower at the maximum.

Because the table tennis ball is influenced by the very complicated elements such as the air inside the ball, the contact with racket, the pressure and the temperature of the atmosphere while flying and so on, it is very difficult to do an accurate theoretical analysis of fluid hydrodynamics of the ball. The purpose of this study was to compare the initial velocity, spin and deceleration of the 40mm ball with the 38mm ball, in order to show the influences on table tennis skill.
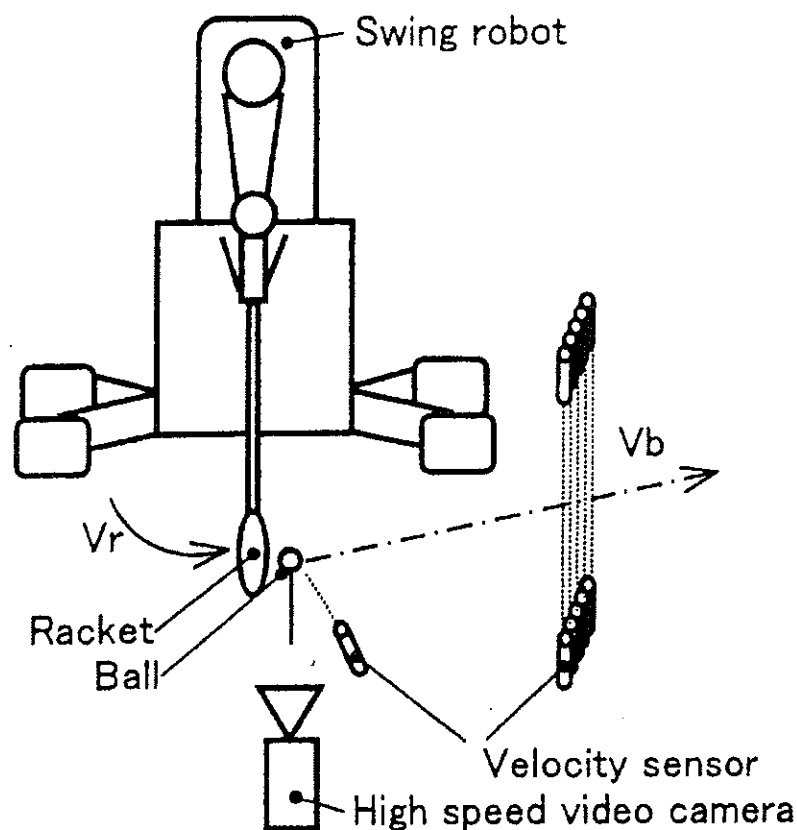
Figure 1.   Experimental setup for measuring initial velocity and spin by using a golf swing robot

2   Methods

2.1 Measurement of initial velocity and spin

To measure the ball's initial velocity and spin, which are the two important characteristics of the table tennis ball, a test of ball hitting was designed. In order to get a constant hitting condition for every ball, a swing robot (Figure 1) was used. Copying the human golf swing motion, the swing robot was composed of a trunk and an arm which can swing freely. The arm was controlled by a servo motor, and its optional swing speed could be selected in different steps.

A racket for hitting the ball was installed in the tip of a shaft which was fixed on a robot arm. The ball hitting was done to a stationary ball put on a soft tube. The hitting angle of the racket could be selected by an adapter, so the ball hitting could be done in a cut or drive stroke. The initial velocity as the ball left the racket was measured by a speed sensor installed 1m from the contact point.

To measure the ball spin, the impact angle of the racket was changed in 5 steps, and the speed of the racket was fixed at 15 m/s. In this test, it was confirmed that few changes happened to the racket speed from 14.95m/s-15.11 m/s, even with the different impact angles of the racket. Therefore, it is considered that the ball contact was carried out in a reproducible manner. The ball was videotaped right after it left the racket by using a high-speed video camera (Kodak HS4540) operating at 4500 Hz. The changes of the ball spin angle were read from markers previously printed on the balls (Figure 2).

1	2	3
0	0.007	0.013

Time (s)
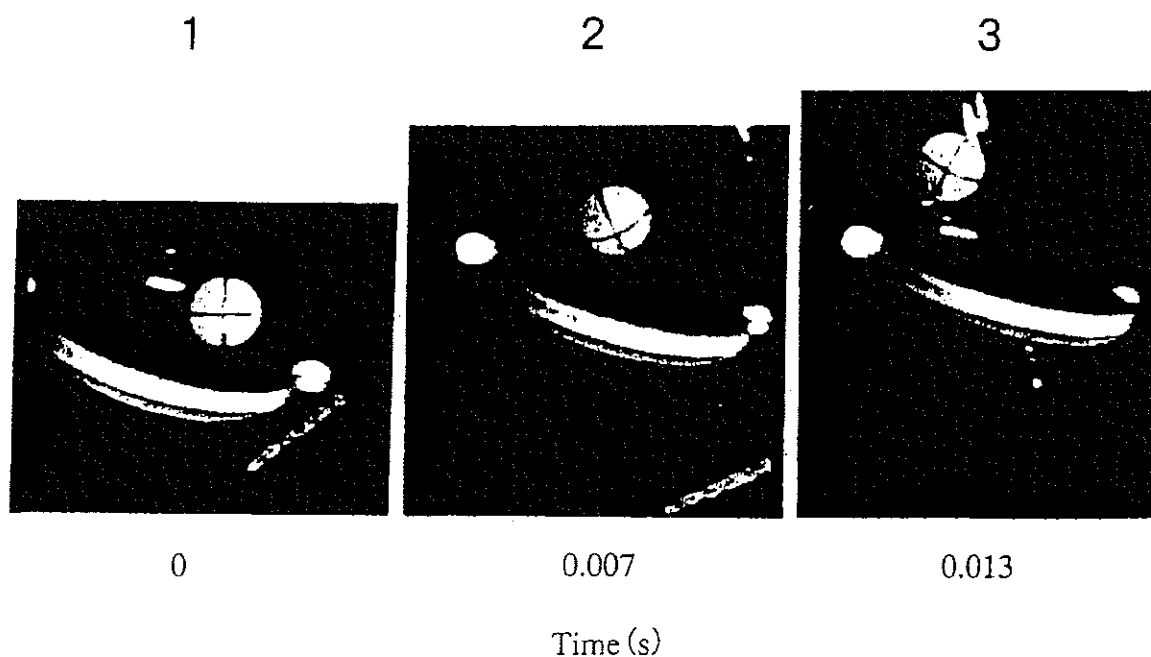
Figure 2.   A sequence of pictures for measuring ball spin

The coefficient of restitution of balls was calculated by the following formula.

$$(v'-V')/(v-V)=-e \cdots (1)$$

The v and v' were the ball speeds before and after contact and the V, V' were the racket speeds before and after ball hitting. From the hypothesis of v=0, V=V', the coefficient of restitution was decided from (1)

$$e=(v'/V)-1 \cdots (2)$$

The ball used for the hitting test was an official ITTF three-star ball (Table 1). In the test, a shake-hand type racket with reverse soft rubber was used. One more kind of larger ball (44 mm in diameter, 2.3 g in weight) was added to the hitting test.

Table 1. Physical characteristics of test ball

	New ball	Present Ball
Diameter (mm)	39.9 ± 0.1	37.8 ± 0.1
Weight (g)	2.71 ± 0.02	2.49 ± 0.02

Measurement condition: 23 ° C, 50% R. H

Sample number of ball: 12

2.2 Deceleration of the ball

Usually after the ball leaves the racket, the ball will decelerate because of air resistance. In this study, in addition to measuring the initial velocity of the ball, the deceleration was measured. A ball shot machine was set up on one end of a table for projecting the three kinds of balls. The ball deceleration was calculated from the initial velocity immediately after being projected, and the average velocity the ball went though over the both ends of the table at one bound.

2.3 Rally time test

To identify the differences of rally times between the 40mm and the 38mm balls in actual play, three kinds of strokes, drive, chop and service (side spin, side-back spin and back spin) were videotaped with a home video camera. The strokes were played by six elite players who were the members of a university table tennis club. The video camera operated at 60 Hz from a position at the side of the table. The rally time of the drive and chop were calculated by a round trip of the ball, and the time of service was calculated between the time the ball left the racket and the time it reached 0.90 m beyond the net.

2.4 Limit of this study

It is obvious that the increase of the mass and the diameter of the table tennis ball will have some influence on both the speed and the spin. However, it is difficult in testing to distinguish clearly the independent factors of the mass and

the diameter. Therefore, in this study, only the combined influences of the increase of mass and diameter on speed, spin, deceleration and rally time of the ball were analyzed.
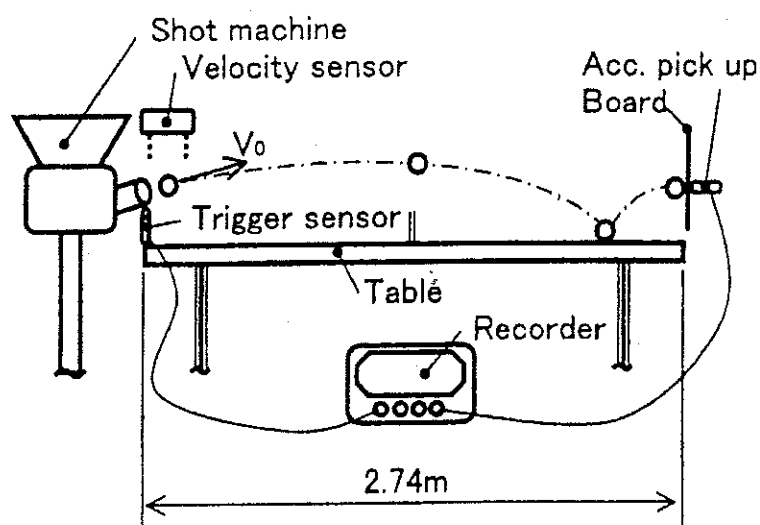
Figure 3. System for measuring ball velocity

3 Results and considerations

3.1 Influences on initial velocity

The racket face was set at a right-angle to the ball- flight axis. Every ball leaving the racket was observed by a high-speed video camera to confirm that it did not spin. Based on preceding studies, the speed of racket was varied from 5 m/s to 23 m/s. Figure 4 shows the initial velocities and the coefficients of restitution for the three kinds of balls at 5 speeds. The ball's initial velocities became greater with the increases of the hitting speed of the racket. On the other hand, the coefficient of restitution tended to decrease as the speed increased. In comparing three kinds of balls, it was clear that the large ball's speed and coefficients of restitution were the smallest. However, the speeds of the 40mm ball were only a little smaller than those of the 38mm ball: the speed difference between the two kinds of balls was only about 1-2% (Figure 5) when the hitting speed was more than 10 m/s.

This result of 1-2% shown above was much smaller than the 13 % deceleration of the 40mm ball reported by Zhang (2000). As there are no details about the test method in the report, two reasons for the different results can be supposed: one is the quality of balls and another one is the measuring methods in Zhang's test.

The impression of the 40mm ball for almost all the players including the world champion was that, "a deceleration of ball initial velocity can be felt while

stroking, and a slowdown of the ball speed can be felt while receiving" (World Table Tennis, 2000). Therefore, even though the difference of initial velocities between the 40mm and 38mm ball was only 1-2 % players seem sensitive to this difference. Also, the differences may have some influence on the skills of table tennis.

3.2 Influence on spin

To create spin, the racket surface was fixed at an angle that was set between 15°and 75°in 15°increments. The racket speed was set at 15 m/s

Figure 6 shows the spins and initial velocities of the ball. We can see the increase of spin and the decrease of the initial velocity, as the racket angle increase with all three kinds of ball. The initial velocities had the same decelerating tendency as the perpendicular hitting (Figure. 4) in all the balls and at all the angles. Comparing the spin of the three kinds of ball reveals a clear difference. That is, compared with 38mm ball, the spin of the 40mm ball decreased by 5-10 r/s, or 5-20 %.

According to this result, the spin decrease was smaller than the 23 % reported by Zhang (Zhang, 2000) for the 40mm ball.

Almost all the players commented about 40mm ball, saying, e.g.," We can feel the reduction in the spin on the ball " (World Table Tennis, 2000). In table tennis, spin is an influential weapon to make the competitor make mistakes. It is expected that players' mistakes will decrease, and the rallies will increase in length because of the decrease of the spin. Also, the decrease will possibly bring a disadvantage to the players who use backspin tactics.

3.3 Influence on deceleration

The initial vector and the average scalar of the 40mm and 38mm ball are shown in Figure 7. It was found that the average speed of the two kinds of balls decreased about 10-20 % compared with the initial speed, and this decrease did not depend on the initial velocity. The regression straight lines were made by the minimum square method from the measurements for each ball and the deceleration percentages of both balls were compared from the inclinations, but no difference was observed in the deceleration between the two kinds of ball. But, because the ball speed from the machine was only 14 m/s maximum, the results of this test can not refer to a faster ball, such as smash and fast drive balls.

3.4 Influences on rally time

Table 2 shows the rally times of the drive, chop and the average of three kinds of service. (back spin, side-back spin and side spin). From table 2, we can see the time of drive was about 40 % shorter than the chop in a round trip. For the difference in the rally time, the 40mm ball was about 0.04 seconds longer than 38mm ball in drive and chop. For the rate of increase in the time, the drive was 4.4 % and chop was 3.2 % on 1 % level of significance for both. For the time of service, 3.9 % increase of 40mm ball was observed, but there was no significance (5 % lever).

The time differences of the 40mm ball and 38mm ball in rally and service were about 3-4%, and this time difference would be a important matter which can

not be ignored in the delicate technology of table tennis. The causes of the time increase can be considered to be the decrease of the initial velocity of the ball. Because of the lower speed and bigger size, the 40mm ball becomes more easy to judge than the 38mm ball both in time and space, so fewer misses and longer rallies can be predicted.

4   Conclusions

In this study the initial velocity, spin, deceleration and rally time in play were measured by using a swing robot and a speed measurement system. It can be assumed that the changes of the diameter and weight will have some influence on the player's performance.

(1) The initial velocity of the 40mm ball was 1-2 %, and the ball spin was 5-20 % less than for the 38mm ball.

(2) No difference in deceleration between the 40mm ball and the 38mm ball was observed.

(3) The average rally times of the 40mm ball were 2-4 % longer than the 38mm ball for drive and chop shots.

5   References

Yoshida K et al. (1995) Three-dimensional analysis of moments of table tennis services. The System of the Human. Biomechanics of Human Moment. Editorial board of the 13th Japanese Society of Biomechanics Conference. pp. 318-323.

Yoshida K et al. (1997) Three-dimensional analysis of a forehand flick stroke in table tennis. Biomechanics of Human Moment. Editorial board of the 13th Japanese Society of Biomechanics Conference. pp. 294-299.

Zhang X (2000) A technical investigation into the ITTF large ball tournament in Suzhou. The 6th ITTF Sports Science Congress. Kuala Lumpur.

World Table Tennis (2000) Vol.37. 6. pp. 61-64.