Effect of different playing surfaces of the table on ball bounces in table tennis

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Abstract: the purpose of this study was to measure the coefficient of restitution, ball spin and coefficient of friction (CoF) that are generated between the table tennis table and the ball. Nine combinations consisting of three table tennis tables and three balls were tested, each from three manufacturers (manufacturers of tables: mfr.A, mfr.B, mfr.C, manufactures of balls: mfr.B, mfr.C, mfr.D). The process was measured with two methods. The first method was to pull a triangular raft placed on top of three balls across the playing surface at a constant speed with a mini motor. The second method was to photograph the balls before and after bounce after being shot out from a robot machine at backspin or topspin with a high-speed camera. These methods are shown in "The ITTF Table Technical Leaflet T1". The first finding indicated that the CoF was the lowest when the ball made by mfr.C is combined with any table. In particular the CoF was the lowest for the combinations using the ball made by mfr.C and the table made by mfr.B. The first finding made it clear that the ball slippage varied according to the combination of table tennis tables and balls of different brands. The second finding indicated that the frictional force was produced in the direction of the ball when the rotation speed of the topspin ball before bounce reached 3000 rpm or more. It was revealed that the rotation speed decreased (21.7 %) and speed increased (7.2 %). The CoF was produced in the opposite direction when the balls were hit with a backspin in any rotation speed. The rotation speed decreased by 26.5 % and 18.1 % when before bounce it was 2500-3500 rpm and 4500-5500 rpm respectively. The resilience of the table tennis table made by mfr.C was lower than other tables in both topspin and backspin. The table with the highest CoF value generated in backspin was table tennis table by mfr.A, followed by mfr.C and mfr.B in this order. On the whole, the CoF was low for any combination of the ball made by mfr.C and the three different table tennis tables. It follows from these results that the trajectory of the ball varied in small amounts based on the CoF between the table tennis table and the ball. That is, when hitting the ball, the player's performance was affected depending on which combination of table tennis table and ball was used. In conclusion, in order to raise the performance of a player's hits, it is necessary to understand the characteristics of both spin and trajectory when using different combinations of table tennis tables and balls.

Keywords: coefficient of friction (CoF), coefficient of restitution, table tennis table, ball, combination

1. INTRODUCTION

The ball's spin is one of the factors that have a big effect on player's performance in table tennis. So far several studies have been made on table tennis ball spins in Japan and other countries [1-5]. Many of these studies have quantified the ball rotation speed of top players. These are important data to consider for coaching.

The ball's spin varies according to the effect of how the racket hits the ball, the properties of air and also how the ball bounces on the table. The table was designed in accordance to criteria established by ITTF. The type such as thickness of top board and material of the table differs according to manufacturers. Thus the ball's bounces change when using a variety of tables. The Japan national training center has various tables that are used around the world for training top players. Experienced players perceive a subtle change in the ball's bounce. In spite of the ball bounce changes according to the properties of playing surface, there have been very few studies about it. Therefore, the characteristic of the ball bounces is not well understood.

The purpose of this study is to clarify the impact of the playing surface on changes in both spin and bounce. Specifically, the study will focus on the coefficient of restitution, spin and coefficient of friction (CoF) that are generated between the table tennis table and the ball.

2. METHODS

This research used two experiments. The first consisted in measuring the CoF by traction. The second was photographing the moment of the ball's bounce on the table with a high-speed camera. Three different tables (mfr.A, mfr.B, mfr.C) and balls (mfr.B, mfr.C, mfr.D) were used in each experiment. The experiments measured all nine possible combinations of the tables and balls.

2.1 Measurement of friction coefficient by traction

A triangular raft placed on top of three balls was made to measure the CoF. A mini motor that had one of three different weights pulled the raft by a miniature load cell in a horizontal direction at a constant speed for 20 seconds (Fig.1). The weights were 80 g, 120 g or 160 g. The measurement items were 27 in total (Table 1). Each measurement item was pulled ten times.

The normal loading (Fv) and the horizontal resisting force (Fh) were measured when the raft was pulled. The CoF (μ) was calculated with the equation (1). The interval analysis of the CoF calculated was for 10 seconds (1 kHz) after the horizontal resisting force reached a maximum and became stable. The average dynamic CoF for 10 seconds was a single measured value. The dynamic CoF was the average that subtracted the maximum and the minimum from the 10 measurements values.

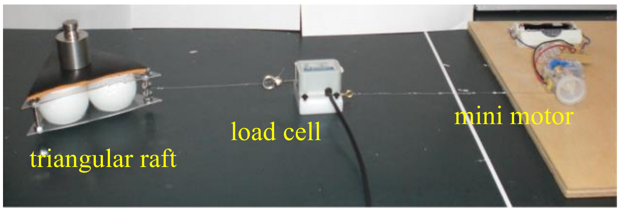

Fig. 1 Measurement of CoF by traction

Table 1 The fractional measuring items

The 27 measuring items				
Weights		Table' brand		Ball' brand
80g	×	mfr.A	×	mfr.B
120g		mfr.B		mfr.C
160g		mfr.C		mfr.D

$$\mu\ (\text{CoF}) = \frac{Fh\ (\text{horizontal force})}{Fv\ (\text{normal loading})} \qquad (1)$$

2.2 Recording the ball bounces that were given various rotation speeds with a high-speed camera

The moments the ball bounced on the table after being shot out from a machine were photographed by a high-speed camera (1200 fps) (Fig. 2). The rotation speed of the ball that shot out from the machine was on three levels (2000 rpm, 3000 rpm and 4000 rpm) at topspin or backspin. The measurement items were 54 in total (Table 2). The balls were bounced ten times within the range of photographing in each measurement.

The images were imported to a personal computer, and analyzed by using the image analysis system (frame-DIAS II, frame-DIAS IV). The ball rotation speeds were derived from time taken for one revolution. The angle rates were derived from these values. The incidence angle (θ_0), the reflected angle (θ_1), the impingement rate (v_0) and bounce-off velocity (v_1) were computed from recorded coordinate values that digitized the lowest point of the ball. Next, the coefficient of restitution (e) and CoF (μ) were calculated according to (2) and (3) (Fig. 3).

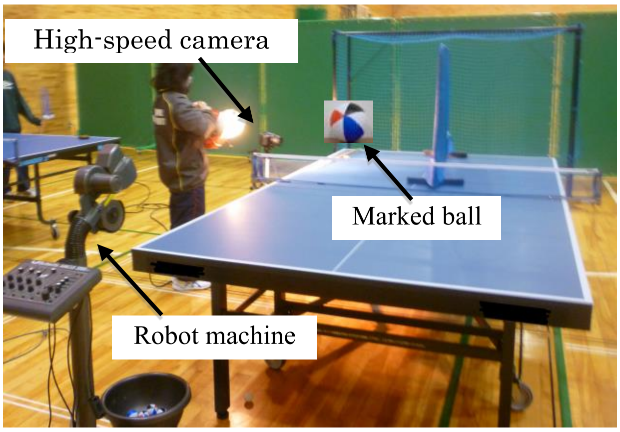

Fig. 2 Photographing the bounces of the ball

Table 2 The items of photographic measurement

The 54 measuring items						
Rotation speed		Rotation direction		Table' brand		Ball' brand
2000rpm	×	Topspin	×	mfr.A	×	mfr.B
3000rpm		Backspin		mfr.B		mfr.C
4000rpm				mfr.C		mfr.D

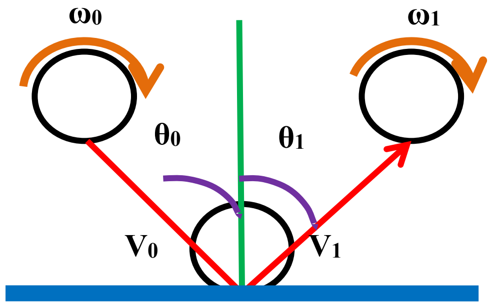

Fig. 3 Values of the bounce ball for calculating

$$e\ (\text{coefficient of restitution}) = \frac{v_1 \cos\theta_1}{v_0 \cos\theta_0} \qquad (2)$$

$$\mu\ (\text{CoF}) = \frac{2r(\omega_1 - \omega_0)}{3(1+e)\cos\theta_0} \qquad (3)$$

3. RESULTS AND DISCUSSION

3.1 The CoF of fractional measurement

The results of CoF that compared the tables of three kinds with respect to the three balls are shown in Fig. 4 (*$p < 0.05$, no mark $p < 0.01$). The CoF that combined the table made by mfr.C with the ball made by mfr.D was highest when the raft had weights 80 g. The CoF was high in the order of table mfr.A ≧ mfr.C > mfr.B when using the ball made by mfr.C in cases which pulled other weights. The CoF order from highest to lowest was table mfr.C ≒ mfr.A > mfr.B when using the ball made by mfr.B. The CoF had extremely low values when the ball made by mfr.A was combined with the table made by mfr.C. When the ball made by mfr.C was combined with any of the three tables, the CoF was lower than the combinations using the other balls. It was found from these results that the CoF varied according to the combination of the table and ball produced by different manufacturers and materials.

3.2 Changes of ball's bounce at various rotation speeds

3.2.1 Comparisons between topspin and backspin

Changes of before and after bounce in topspin balls are shown in Fig. 5. The CoF was produced in the opposite direction of the ball bounce when the topspin ball rotation speed before bounce measured 2000 rpm to 3000 rpm. Furthermore the rotation speed increased by 9.4 %. When the topspin ball rotation speed revolved up to 4000 rpm through 5000 rpm, the CoF was produced in the ball's bounce direction. Moreover, the ball rotation speed decreased by 21.7 %. Changes before and after bounce in backspin balls are shown in Fig. 6. The CoF was produced in the opposite direction of the ball bounce regardless of rotation speed when the ball was in backspin.

3.2.2 Manufacturers' comparison and the effects on player's performance

The coefficient of restitution with respect to each table of different manufacturers is shown in Fig. 7 (**$p < 0.01$). The coefficient of restitution produced by the table made by mfr.C had a low value for both topspin and backspin. The CoF with respect to each table in combination with the balls of different manufacturers is shown in Fig. 8 (*$p < 0.05$, **$p < 0.01$). The CoF had tendency to be more in the order of table mfr.A ≧ mfr.C > mfr.B when using the ball made by mfr.D. The CoF had similar tendency even when using the other balls. It was found from these results that the CoF was high in the order of table mfr.A > mfr.C > mfr.B on the whole. When using the table made by mfr.A, the CoF was significantly higher than when using the other two tables. Finally, the CoF was lowest when using the ball made by mfr.C.

When using the ball made by mfr.D, there was a possibility that the player was able to play in the same way using the table made by mfr.A or mfr.C. Furthermore, there was a possibility that the player was able to hit the balls in the same way whatever the combinations of materials (ball / table) produced by mfr.B or mfr.C. The table made by mfr.B had little change on the rotation speed, the ball speed and the ball angle. That table generates less frictional force than the tables of other manufacturers.

It was found from these measurement results that the change in CoF was in the following order: mfr.A > mfr.C > mfr.B. Moreover, only a small amount of frictional force was generated when the player hit the ball made by mfr.C on any of the tables.

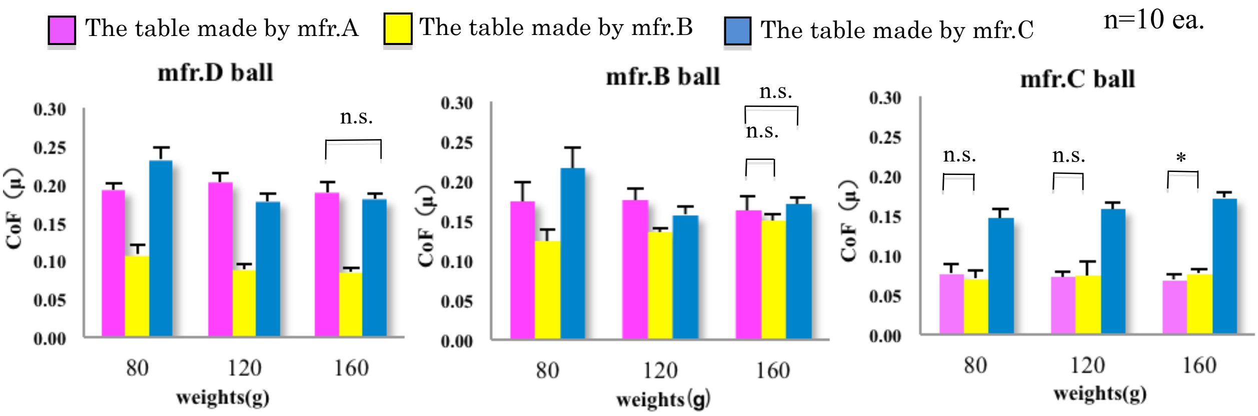

Fig. 4 The dynamic CoF by traction

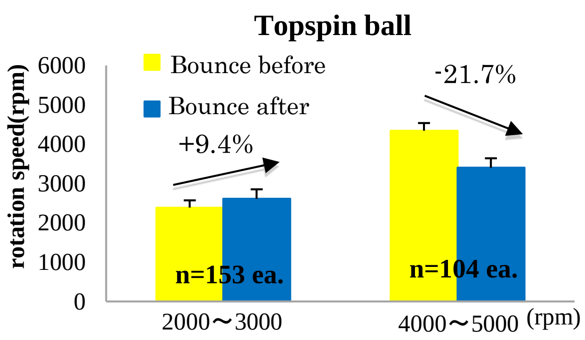

Fig. 5 Changes of rotation speed in topspin ball

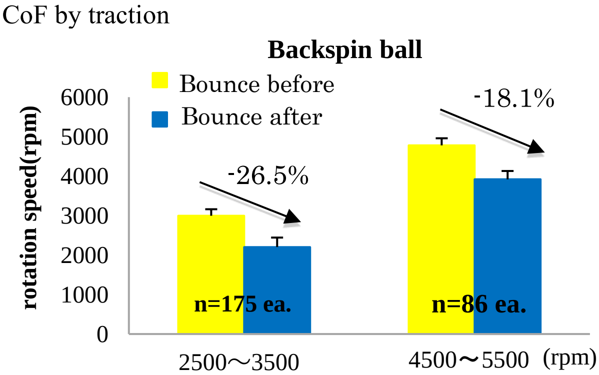

Fig. 6 Changes of rotation speed in backspin ball

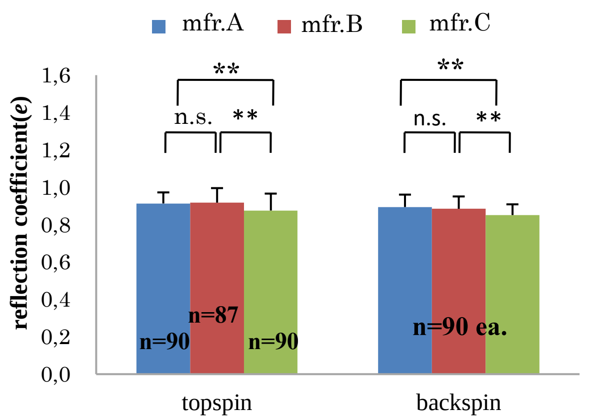

Fig. 7 Coefficient of restitution of each table

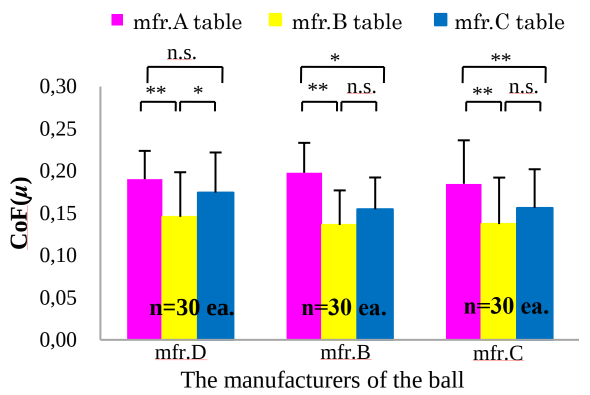

Fig. 8 The CoF by photograph measurement

4. CONCLUSIONS

Until now, there has been no knowledge about the changes in a ball's bounce differing according to the table tennis table used.

From the above results, the CoF between the playing surface and the ball was high in this order: mfr.A > mfr.C > mfr.B. The frictional force was produced in the opposite direction of ball bouncing when the topspin rotation speed of the ball was lower than 3000 rpm. The table made by mfr.C produced small frictional force. And the ball rotation speed, the ball speed and the ball angle had small change before and after bounces. Players need to understand the difference in a ball's bounce that arises when using playing surfaces made by different manufacturers.

Players also need to understand the changes in both spin and trajectory when the CoF between the ball and the table of different manufacturers affects the ball's bounce. The results of this experiment will provide useful information for improving the performance of players' hits. Further research in this area will provide more information on changes in a ball's bounce of other manufacturers not used in this study.

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