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The difference of dynamic elasticity characteristics and stroke effect between two types of new material seamed plastic table tennis ball

Jiajie Tian, Zerong Wang & Yi Xiao

The diameter and weight of different brands of table tennis ball will affect the ball's elasticity and stroke. The purpose of this study is to analyze the difference of the dynamic elasticity and stroke effect between the two brands of new plastic ball. A self-made experiment was designed to test the dynamic elasticity characteristics of DHS D40 + and Nittaku 40+. Table tennis players (N = 18) were randomly selected from the China Table Tennis College (M_{age} = 15.16 ± 2.41; M_{height} = 1.59 ± 0.32 m; M_{weight} = 45.72 ± 5.17 kg). Each participant was righthand shake-hands grip. A speedometer was used to record the ball speed and a high-speed camera was used to measure the spin speed. Data normality was verified by using the Kolmogorov-Smirnov test. The independent t-test was conducted to assess the differences of the dynamic elasticity and stroke effect between the two types of plastic ball. Results showed that the rebound speed and decrement rate of DHS D40 + and Nittaku 40 + both increased with the increased falling speed, respectively. When falling at high speed, there was a significant difference of dynamic elasticity between DHS D40 + and Nittaku 40+ (p < 0.01). There was also a significant difference in the ball speed and spin speed between the two types of new material seamed plastic ball during the backhand backspin stroke (p = 0.041, p = 0.022, respectively), and the ball speed and spin speed of DHS D40 + were higher than that of Nittaku 40 + ball. Compared with the DHS D40+, the Nittaku 40 + has a faster rebound speed, higher rebound height, and better dynamic elasticity. Therefore, under same striking conditions, when hitting the Nittaku 40 + ball, players need to increase the swing distance and hit the ball with more strength to improve the ball speed and rotation speed; increase the spin and decrease the ball's rebound height of the serve.

Keywords Table tennis, New plastic ball, Elasticity, Physical characteristic, Falling speed, Rebound speed

Background

In May 2011, the ITTF decided to ban celluloid table tennis balls after the London Olympics. Subsequently, the new plastic ball was introduced and made its debut in the ITTF World Cup held in October 2014. According to the different manufacturing processes, the new plastic balls can be divided into two types, seamed plastic balls and seamless plastic balls[1], both of which are made of ABS material. ABS material has high elasticity, hardness, and certain toughness. Therefore, the new plastic ball with the new material exhibits high hardness, good elasticity, and fast ball speed[2]. Compared with the seamless plastic ball, the seamed plastic ball is used more frequently in international table tennis competitions. Among seamed plastic balls, the Double Happiness D40+ (DHS D40+) and Nittaku 40 + are two main types of the new plastic ball designated for international events[3]. The DHS D40 + is the most commonly used table tennis ball in major international events, such as the Olympics, World Championships, and World Cup. Nittaku 40 + is also designated as the official ball for important international events many times, including the World Championships, Asian Championships, Asian Cup, and so on. A comparison of the physical properties of the two seamed plastic balls, such as mass, diameter, and rebound height, is shown in Table 1. It can be seen that the mass and diameter of Nittaku 40 + seamed plastic ball are slightly heavier and larger than that of DHS D40 + seamed plastic ball respectively, and the rebound height of Nittaku 40 + is slightly higher than that of DHS D40 + seamed plastic ball (Table 1).

China Table Tennis College, Shanghai University of Sport, Shanghai 200438, China. email: cutexxx@163.com

Category	DHS D40+	Nittaku 40+
Weight	2.53–2.64 g	2.72–2.75 g
Diameter	39.60–40.46 mm Standard deviation ≦ 0.06 mm; Minimum diameter deviation ≦ 0.25 mm	40.31–40.49 mm Standard deviation ≦ 0.01–0.05 mm
Rebound Height	241–261 cm	256–260 cm
Appearance	White or orange color, no gloss, with neat seam	White or orange color, no gloss, with neat seam

Table 1. Comparison of physical characteristics between DHS D40+ and Nittaku 40+.

Different tournament organizers designate different brands of table tennis balls for their competitions. However, the diameter and weight of the balls vary slightly from brand to brand due to different manufacturing processes. Studies show that changes of the ball diameter and mass will directly lead to changes in the ball's physical properties, such as hardness and elasticity[4]. The elasticity of table tennis is an important factor that affects the stroke effect, which includes the ball speed, rotation speed, placement, and trajectory. The weight increase of the new plastic ball results in a faster falling speed after hitting the ball, while the rebound height will be increased as well[1,5,6]. Bao et al. analyzed the rebound characteristics of new plastic balls and found that, compared to other physical properties, the change in the ball mass made the rebound characteristics of the new material plastic ball more obvious[7]. At the same time, the increase in mass decreases the spin speed of the ball[8]. Furthermore, new plastic balls with larger diameters have a greater cross-sectional area and encounter stronger air resistance during flying, resulting in a drop in ball speed[9]. A study revealed that the reduction in speed for forehand smashes ranged from 0.0 to 7.9%, while the reduction in forehand high-loop spin ranged from 2.0 to 7.7%[10].

The change of ball elasticity characteristics will directly affect the stroke effect and then put forward new requirements for athletes' technical and tactical training and competition[10]. Zhang et al. conducted a survey around athletes' subjective perception of the new plastic ball and concluded that most athletes perceived differences in the ball's size, along with variations in its rebound height and the sound it makes upon impact[11]. According to Kawazoe, there was a different feeling when players striking different brands of new seamed plastic table tennis ball, and the difference would affect the players' application of techniques and tactics[9]. Wei et al. investigated the influence of different sizes of table tennis ball on players' technique and tactics and found that balls with larger diameters led to significant fewer points scored in players' offensive play after receiving a serve. Therefore, players need to adjust their stroke techniques according to the variations in ball size and weight[1].

To sum up, the change in table tennis ball diameter and mass will directly lead to the change in other physical characteristics, such as hardness and elasticity, thus affecting the stroke effect, such as ball speed, rotation speed, placement, and trajectory[4].

The latest requirement set by the ITTF for the ball elasticity detection method is to hold the ball close to a ruler and release it from a specific height, so that the ball can drop in free fall, then to measure the elasticity according to rebound height. This method is widely used in equipment quality control before formal table tennis competitions, so as to maximum ensure fair play. However, although it can detect the ball elasticity, the initial velocity when the ball starts to fall is zero[5]. In other words, the detection method is closer to testing the "static elasticity" of a table tennis ball, that is, without considering other external forces applied on the ball except the ball's gravity. However, in actual training and competition, a table tennis ball is hit by players at first, then starts to move at different initial speeds and finally hits the Table[12], which causes the situation that the current elasticity detection method does not completely match the actual application scenario. Therefore, testing the rebound characteristic of the ball after hitting the table with different speed levels, which is referred in this study as "dynamic elasticity", has more practical value in guiding the actual training and competition of table tennis players. In this study, a table tennis dynamic elasticity test device was designed to test and analyze the differences of the dynamic elasticity characteristics and stroke effect between two different brands of new seamed plastic balls, DHS D40 + and Nittaku40+, to help coaches and athletes make targeted training plan according to different event official ball, to minimize the impact caused by different ball brands, thus to improve the stroke effect and achieve better performance. We hypothesized that there is a difference in the dynamic elasticity characteristics and stroke effect between the two different brands of table tennis ball, with Nittaku 40 + having better dynamic elasticity than DHS D40+, and DHS D40 + having faster stroke speed and stronger rotation compared to Nittaku 40 + under the same stroke conditions.

Methods
Dynamic elasticity test
Self-made experimental set-up

In this study, the self-made dynamic elasticity experimental device (Fig. 1) was used to generate different levels of initial speed of table tennis balls to test the dynamic elasticity characteristics of DHS D40 + and Nittaku 40+, two typical brands of new plastic balls. The selected experiment ball was DHS D40+ (3-star) of Double Happiness Company (DHS) and Nittaku 40+ (3-star) of Nittaku Company.

A circular area was marked with a diameter of 4 cm on a horizontally fixed table, as the target area where the test balls hit after falling in air during the test. The self-made dynamic elasticity device was installed approximately 30 cm vertically above the circular area. The dynamic elasticity device consisted of a PVC pipe with 8 cm diameter, of which both ends were open to let the ball drop. The elastic device also consisted of a spring with a rubber strip. Before starting the experiment, the DHS D40 + and Nittaku 40 + test balls were held at

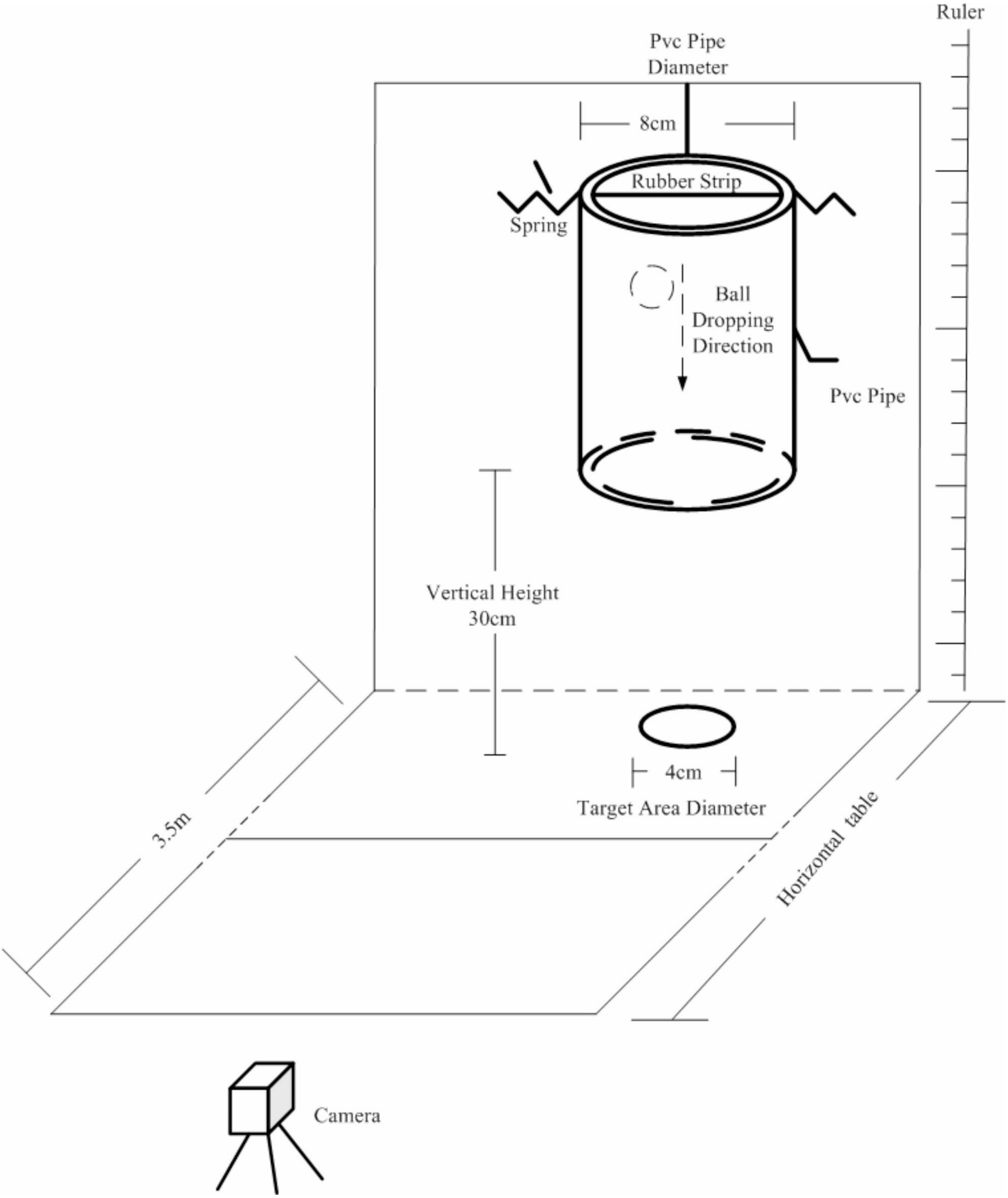


Fig. 1. Self-made dynamic elasticity experimental set-up.

the upper end of the PVC pipe to ensure that after being applied with initial speed, the test balls could vertically drop and hit the circular target area on the table. Testers pulled the spring to different heights to obtain different falling speeds. Then the falling speeds data were divided into three groups (low, medium, and high) based on the distribution range of the data. A pre-experiment was conducted before the formal experiment to examine the reliability and validity of the testing method, and the results were shown in Table 2.

A camera (Sony, FDR-AX100E) was used to collect the trajectory of the ball falling and rebound after hitting the table during the experiment, and the Kinovea software (Kinovea software company, version 0.8.27) was used

Lift height (cm)	Brands	Test 1	Test 2	ICC	TE (%)
30	DHS D40+	5.07±0.09	5.06±0.12	0.80	6.4
	Nittaku40+	6.59±0.31	6.56±0.28	0.98	4.5
50	DHS D40+	13.20±0.03	13.22±0.03	0.93	1.1
	Nittaku40+	13.41±0.31	13.41±0.30	0.99	1.5
70	DHS D40+	24.47±1.36	24.49±1.33	1	2.5
	Nittaku40+	21.68±0.88	21.69±0.88	1	2.7

Table 2. Test-retest reliability of three pulling height. Pulling height: the height of the elastic band lifting upwards. Data are mean ± SD. *ICC* intraclass correlation coefficient, *TE* typical error of measurement.

to process the falling and rebound trajectory and calculate the average speed of falling and rebound process, then accordingly calculate the rebound speed decrement rate. The formula was as follows:

$$\text{Rebound Speed Decrement Rate} = (\text{Falling Speed} - \text{Rebound Speed})/\text{Falling Speed} \times 100\%$$

The elasticity characteristic and the difference between two brands of new plastic balls were analyzed according to different levels of falling speed and its corresponding rebound speed and rebound speed decrement rate. In this paper, the falling speed of the balls during the test was divided into three levels: slow speed (2~10 m/s), medium speed (10~16 m/s), and high speed (16 m/s above).

Experimental protocol

To simulate the different levels of flight speeds from the player after hitting the ball with a racket, this study generated different falling speeds by stretching the spring vertically upward to different heights and then releasing it hit the test balls. Each kind of new plastic ball was tested 10 times at each experiment height.

Stroke effect test

Participants

This study was approved by the ethics committee of Shanghai University of Sport and was performed in accordance with relevant guidelines or regulations. Table tennis players (N=18) were randomly selected from the China Table Tennis College ($M_{age} = 15.16 \pm 2.41$; $M_{height} = 1.59 \pm 0.32$ m; $M_{weight} = 45.72 \pm 5.17$ kg). Each participant was right hand shake-hands grip. All participants' technical levels remained the same (National grade one). All subjects or their legal guardians were informed of the process of research and provided a written informed consent form before the experiment.

Data collection instruments

In order to examine the difference of the stroke effect between the two types of new material seamed plastic ball (DHS D40+ and Nittaku 40+), a speedometer (BUSHNELL Company, USA) was used to record the ball speed, a high-speed camera (Miro R111, USA) was used to measure the spin speed, and a serving machine (V-989 H, Nittaku Company) was used to serve the balls. Each experimental ball was marked with T-mark on its surface using a black marker (Fig. 2). After each stroke, a series of continuous images of the ball flying over the net were captured using the high-speed camera. Then, using the computer processing software of the high-speed camera, the number of frames required for the T-mark on the surface of the ball to rotate around (360 degree) when flying over the net was observed and calculated. Finally, the spin speed of the ball flying over the net was calculated by dividing the sampling frequency of the high-speed camera (4500 fps) by the number of frames required for the ball to rotate around. The equation was shown as follows:

$$Spin\ speed\,(r) = 4500/(\text{x2} - \text{x1})$$

Note: The number of frames in the starting position of T-mark on the ball was x1, and the number of frames after the T-mark rotated one turn was x2. The sampling frequency of the high-speed camera (4500 fps).

Experimental protocol

Participants were asked to warm up for 5 min before formal data collection. They were required to hit the DHS D40+ plastic ball and the Nittaku 40+ plastic ball 20 times respectively using the backhand backspin technique. In the experiment, players struck 20 DHS D40+ plastic balls followed by a 5-minute rest, then struck 20 Nittaku 40+ plastic balls. The ball speed and spin speed when the ball flying over the net was measured by the speedometer and high-speed camera respectively after each player hit the ball (Fig. 3).

Data processing

All statistical analyses were conducted by Statistical Product and Service Solutions (SPSS 23.0, SPSS Inc.). Descriptive statistical analysis was conducted on study variables. Data normality was verified by using the Kolmogorov-Smirnov test. The independent t-test was conducted to assess the differences of the dynamic elasticity and stroke effect between DHS D40+ and Nittaku 40+. An alpha level of 0.05 was used to determine statistical significance.

Fig. 2. Schematic diagram of equipment layout of test.

Results

The difference of Rebound speed between DHS D40+ and Nittaku 40+

The results showed that when falling at slow speed and medium speed levels, there was no significant difference of rebound speed between the DHS D40+ and Nittaku 40+ (both $p > 0.05$), respectively. When falling at a high speed level, there was a significant difference of rebound speed between the two types of new plastic ball ($p < 0.01$) (Table 3).

The curves of the corresponding relation between the falling speed and rebound speed of the DHS D40+ and Nittaku 40+ were shown in Fig. 4. In the slow falling speed stage, with the increase of elastic potential energy which was generated by the elastic experiment device, the falling speed of the ball also increased, while the rebound speed increased accordingly and the trend of the speed increasing curve was relatively stable. When the falling speed increased to medium level, the rebound speed still increased, but the curve slope began to intensify, presenting to move away from the trend line (DHS D40+: $y=0.43x+2.48$; Nittaku 40+: $y=0.51x+3.09$, respectively). When the falling speed reached to fast level, the rebound speed increased steadily along the trend line. However, when the falling speed increased to a certain extent (about 34 m/s for DHS D40+ and about 28 m/s for Nittaku 40+ in this experiment), the ball began to damage, resulting in a sharp decline in the rebound speed.

According to Fig. 4, when falling at slow speed, the rebound speed difference between Nittaku 40+ and DHS D40+ was very small. When falling at medium speed, the rebound speed increase amplitude of Nittaku 40+ was bigger than DHS D40+, and the difference between the two brands of new plastic ball reached to the peak. When falling at high speed, the rebound speed increase amplitudes of DHS D40+ and Nittaku 40+ presented similar and the change of rebound speed began to be stable (Fig. 4).

The difference of rebound speed decrement rate between DHS D40+ and Nittaku 40+

According to Table 3, when falling at slow and medium speeds, there was no significant difference of the rebound speed decrement rate between the DHS D40+ and Nittaku 40+ (both $p > 0.05$), respectively. When falling at a high speed, there was a significant difference of the rebound speed decrement rate between DHS D40+ and Nittaku 40+ ($p < 0.01$) (Table 3).

The curves that presented the corresponding relation between falling speed and rebound speed decrement rate of DHS D40+ and Nittaku 40+ were shown in Fig. 5. In the slow falling stage, the rebound speed decrement rate increased steadily with the increase of falling speed. When the falling speed came to medium and high levels, the rebound speed decrement rate still increased in general, while the fluctuation amplitude intensified and moved away from the trend line (DHS D40+: $y=1.80x+1.54$; Nittaku 40+: $y=1.39x+3.64$, respectively). When the falling speed increased to a certain extent (about 34 m/s for DHS D40+ and about 28 m/s for Nittaku 40+ in this experiment), the test balls started to damage and the decrement rate also increased sharply (Fig. 5).

According to Fig. 5, the rebound speed decrement rate of DHS D40+ and Nittaku 40+ both increased with the increase of falling speed. In the slow and medium speed stages, the difference of rebound speed decrement rate between DHS D40+ and Nittaku 40+ was not significant, and the decrement rate curve fluctuated slightly along the trend line, respectively. In the high speed stage, the decrement rate of the two brands of new plastic balls began to differ, and the rebound speed decrement rate of DHS D40+ was higher than that of Nittaku 40+.

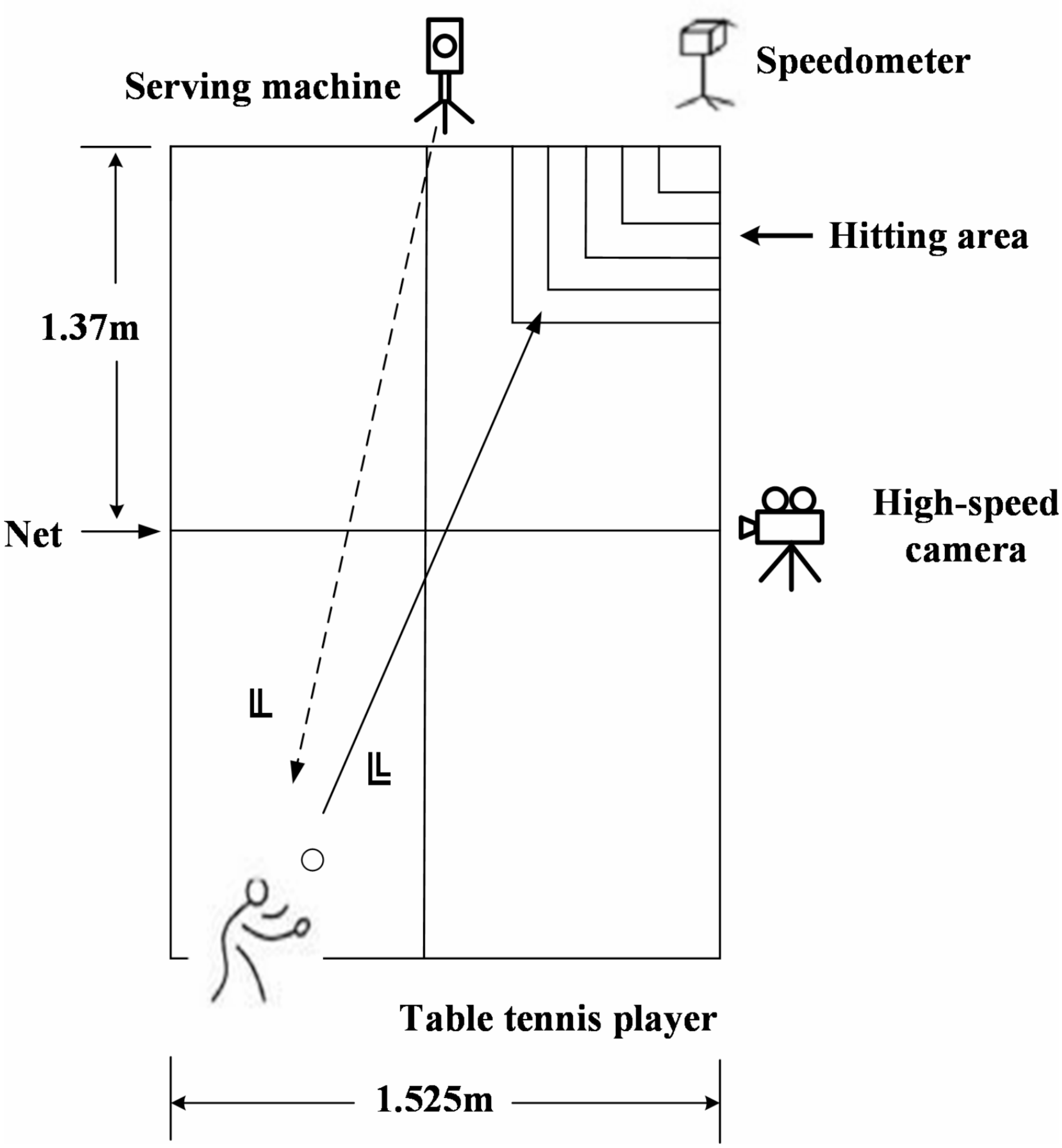


Fig. 3. Stroke test field setup diagram.

	Slow		Medium		High	
	DHS D40+	Nittaku40+	DHS D40+	Nittaku40+	DHS D40+	Nittaku40+
Falling Speed(m·s^{-1})	5.06±2.28	6.29±2.89	13.23±1.36	13.06±1.27	23.86±5.54	21.42±4.41
Rebound Speed(m·s^{-1})	4.47±1.84	5.35±2.12	10.14±0.62	11.09±1.00	12.59±1.48	14.06±1.12
p-value	0.098		0.064		0.001**	
Decrement Rate (%)	10.20±4.39	13.27±5.58	23.07±4.27	22.84±2.79	45.75±7.14**	32.29±9.56
p-value	0.056		0.962		0.000**	

Table 3. Difference of the dynamic elasticity between DHS D40+ and Nittaku 40+. *$p<0.05$. **$p<0.01$.

Comparison of ball broken status between DHS D40+ and Nittaku 40+

In addition, during the experiment, when the falling speed increased to a certain extent (DHS D40+ about 34 m/s, Nittaku 40+ about 28 m/s), there was phenomenon that rebound speed sharply declined and decrement rate rapidly increased for both two brands of new plastic ball. The reason lied in that the test balls started to damage when the falling speed increased to the respective thresholds (Table 4). Data showed that the DHS D40+ new plastic ball began to damage at the falling speed range of 34.53–36.71 m/s, while the Nittaku 40+ new plastic ball began to damage at a slower falling speed range of 27.57–29.30 m/s. This result indicated that the damage

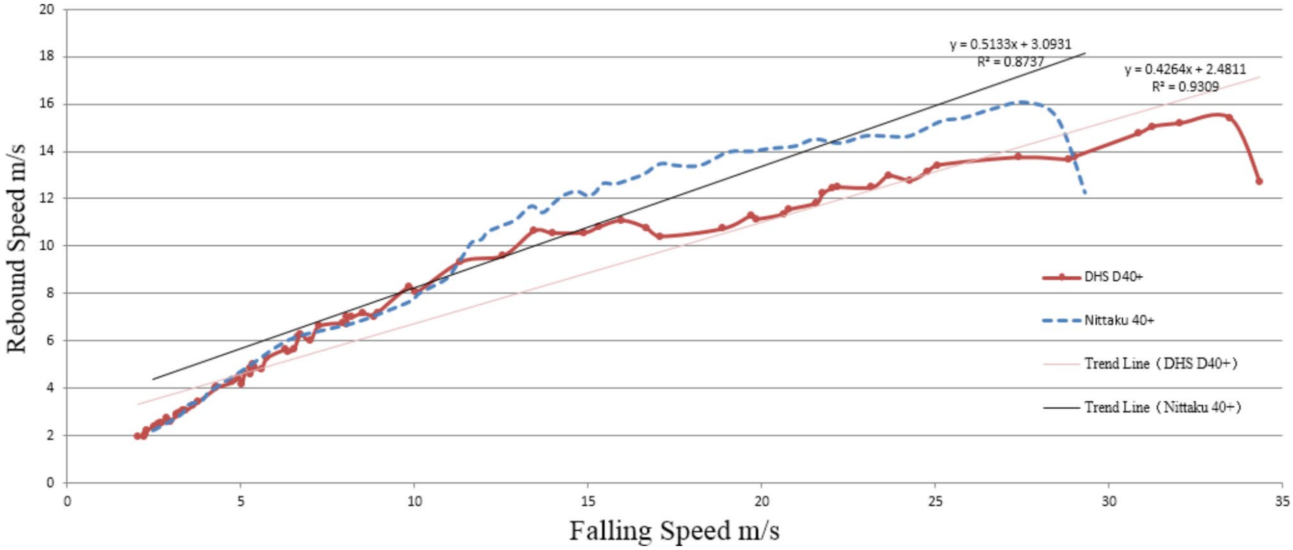


Fig. 4. Comparison of Rebound Speed Curve between DHS D40+ and Nittaku 40+.

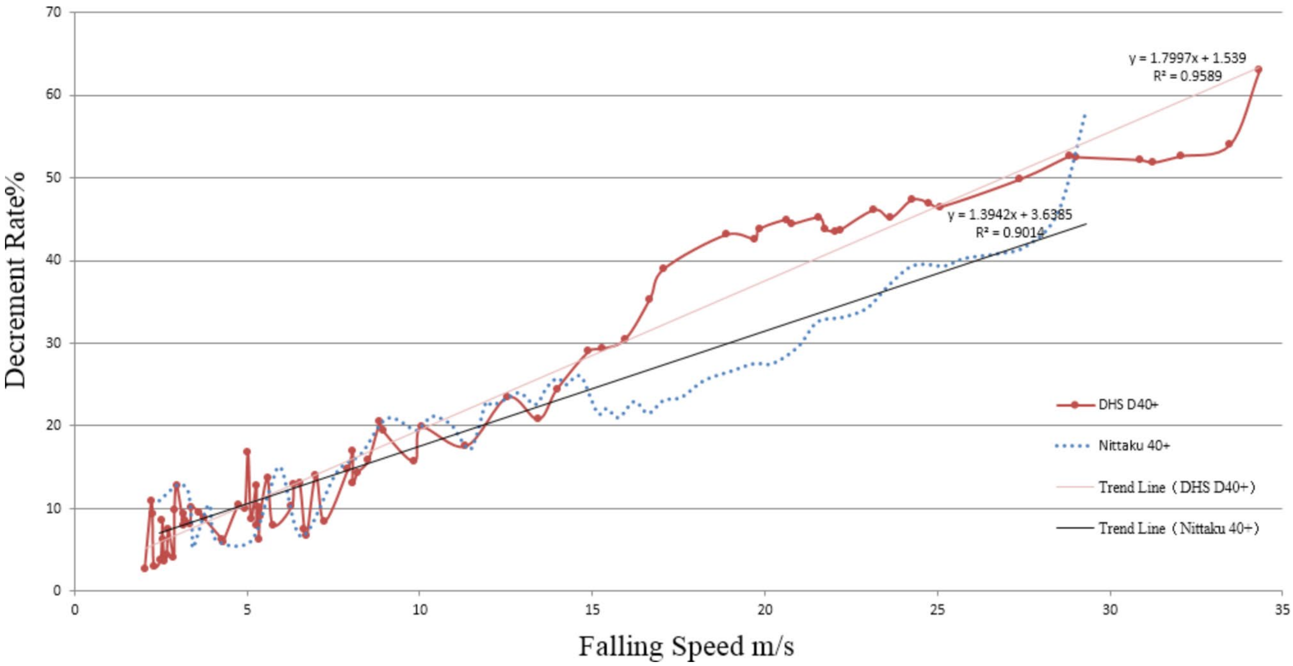


Fig. 5. Comparison of the curve of rebound speed decrement rate between DHS D40+ and Nittaku 40+.

resistance capacity of the Nittaku 40+ new plastic ball was relatively inferior to DHS D40+. Comparing the damaged test balls pictures of DHS D40+ and Nittaku 40+, the DHS D40+ was inwardly concave and featured a groove, while the Nittaku 40+ was directly damaged featuring a large breach (Table 4), indicating that the Nittaku 40+ new plastic ball has bigger hardness and brittleness than the DHS D40+ new plastic ball.

The differences of the stroke effect between DHS D40+ and Nittaku 40+

When striking with backhand backspin technique, there was significant differences in the ball speed and spin speed between DHS D40+ and Nittaku 40+ plastic ball ($p = 0.041$; $p = 0.022$, respectively) (Table 5).

Discussion

The diameter and weight of the new plastic balls vary across different brands due to different manufacturing processes. These variations directly affect the ball's elasticity. Studies found that the changes of diameter and weight of table tennis would affect the ball elasticity, and accordingly would affect the stroke effect[4]. The DHS D40 + and Nittaku 40 + are two main official balls designated for the current international events. At present, the

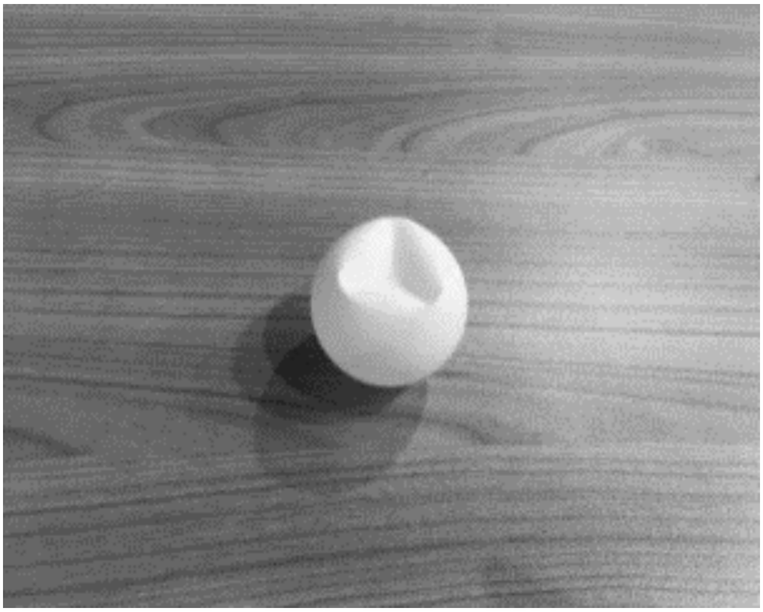
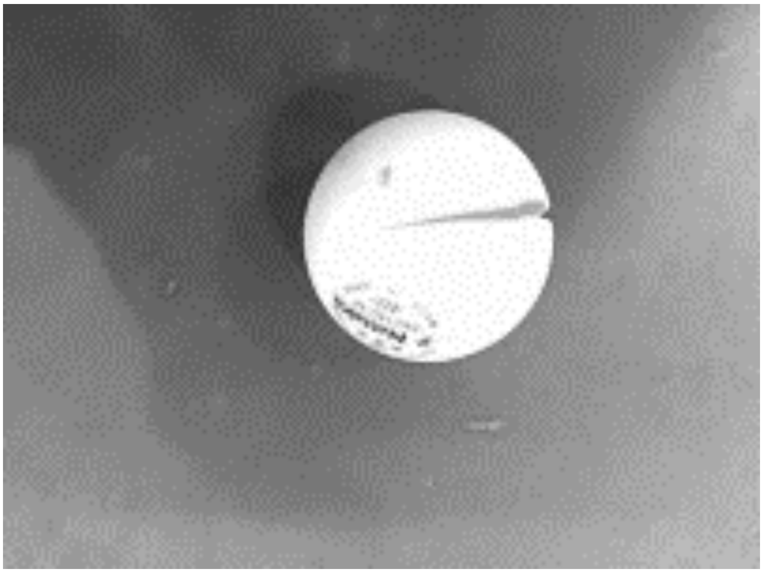
Brands	Damage speed threshold (m/s)	Damaged ball picture
DHS D40+	30.13–32.56	
Nittaku 40+	34.53–36.71	

Table 4. Comparison of ball broken status between DHS D40+ and Nittaku 40+.

	DHS D40+	Nittaku 40+	t-value	*p*-value
Ball speed(m/s)	9.35±1.91	9.10±1.42	2.047	0.041*
Spin speed(r/s)	85.76±16.85	83.15±13.61	2.288	0.022*

Table 5. The difference of the ball speed and spin speed between the two types of plastic ball. *$p<0.05$.

ball elasticity detection standard set by ITTF mainly conducts the static elasticity test of table tennis ball, while in the actual training and competition, table tennis ball is mainly characterized by dynamic elasticity. However, there were very limited amount of researches based on the dynamic elastic characteristics of table tennis ball. Hence, testing and analysing the dynamic elasticity of these two brands of new plastic ball has practical value. Therefore, this study designed the self-made experimental device to test the dynamic elasticity characteristics and analyze the differences of dynamic elasticity characteristics and stroke effect between DHS D40 + and Nittaku 40+, so as to help athletes and coaches to formulate corresponding techniques and tactics for different competition balls[13].

The decreasing rate of rebound speed of Nittaku 40 + is much smaller than that of DHSD40+. Before the ball was damaged, the decrement rate of rebound speed of Nittaku 40 + was relatively stable, while the decrement rate curve of DHS D40 + fluctuated more, indicating that the rebound stability of Nittaku 40 + was better, which may be due to the subtle differences in the internal structure of the two brands of ball. The Nittaku 40 + ball has a more uniform surface and consumes less energy during the movement process, so the rebound speed decrement rate is relatively low, and the rebound speed and rebound height are higher[14] (Fig. 5). When the new plastic balls of both brands hit the table with the same initial velocity, the DHS D40 + has a larger contact area with the table and greater deformation than the Nittaku 40+, resulting in a slower rebound speed than the Nittaku 40+. As a result, the Nittaku 40 + has better dynamic elasticity. It was also found that when the falling velocity (approximately 34 m/s for the DHS D40 + and 28 m/s for the Nittaku 40+) was accelerated, the decrement rate of the rebound speed of the two ball brands increased significantly. When the balls began to break down, the DHS D40 + test balls exhibited inward grooves, while the Nittaku 40 + exhibited significant deformation and rupture, indicating that the DHS D40 + balls were relatively softer and less brittle, while the Nittaku 40 + balls were relatively harder and more brittle[15].

In fast falling stage, the average value of rebound speed decrement rate of Nittaku 40 + was much smaller than DHS D40+. Furthermore, before the ball beginning to damage, the rebound speed decrement rate of Nittaku 40 + was relatively stable in general. In contrast, the decrement rate curve of DHS D40 + featured more fluctuations. This result suggests that Nittaku 40 + performs better in rebound stability, probably caused by the different internal structures of the two brands of new plastic ball. The Nittaku 40 + ball sphere is more uniform, and has slightly bigger hardness and brittleness than DHS D40+. Hence, the deformation of Nittaku 40 + in the contact process with the table is smaller, and the energy wastage in the flying is smaller, so the rebound speed decrement rate is relatively lower, and the rebound speed presents higher, correspondingly showing higher rebound height[16]. This makes Nittaku 40 + present better dynamic elasticity than DHS D40+ (Fig. 5).

The experiment also found that when the falling speed increased to certain extent (DHS D40 + about 34 m/s, Nittaku 40 + about 28 m/s), the rebound speed decrement rate of the two different brands of new plastic ball both sharply increased. The reason is that the DHS D40 + sphere is relatively soft and has low brittleness, so when sphere begins to damage, the test ball is inwardly concave. While Nittaku 40 + has bigger hardness and brittleness, so it is easy to produce deformation and breakdown, and the damage degree of Nittaku 40 + is greater than DHS 40+. Therefore, it is inferred that DHS D40 + performs better than Nittaku 40 + in terms of damage resistance capacity, and the DHS D40 + is more durable than Nittaku 40+[17].

In addition, the difference in the elasticity of the table tennis ball would lead to the change of the rebound height and flight trajectory of the ball after hitting, thus affecting the stroke effect of players[18]. Results showed that the ball speed and spin speed of the Nittaku 40 + is slower than that of the DHS D40 + after hitting. The ball speed and spin speed of the Nittaku 40 + is slower than that of the DHS D40 + after hitting. Compared to the DHS D40+, the Nittaku 40 + has better elasticity, faster rebound speed, higher rebound height, lower ball speed and spin speed, which requires players to increase the power of the stroke to improve the stroke effect. This is consistent with the findings of Li et al. that players need to increase the stroke power to improve the stroke effect when facing larger-sized balls[19].

The differences above will inevitably influence the athletes' techniques and tactics application in their daily training and competition.

For serve technique, it is harder to serve short backspin ball with low trajectory and strong rotation with Nittaku 40 + than DHS D40+, and the serve could easily have high and long trajectory with weak rotation, which will create opportunities for rivals to directly attack, causing a passive situation for themselves[20]. Therefore, when the Nittaku 40 + is designated as the event official ball, athletes should strengthen the training of serve technique in the preparation stage, and improve the serve quality when using Nittaku 40+.

Since using Nittaku 40 + is more difficult to serve short backspin ball with low trajectory and strong rotation, it is harder for players to win the point via attack-after-service tactic, and dominating the game in the first three strokes is harder as well[21]. Accordingly, the rally stage of the competition will be more intense and the overall number of stokes will increase, which puts forward higher requirements for the athletes' attack and defense transformation ability and strong confrontation ability[22].

Finally, compared with the DHS D40+, when playing with Nittaku 40 + new plastic ball, the number of rallies increases and the overall match duration extends. At the same time, before the ball damages and the ball speed sharply declines[23], Nittaku 40 + presents faster ball speed, better elasticity and higher vertical rebound height, which requires athletes to hit the ball with more power, all of which puts forward higher requirements for athletes' physical fitness to cope with training and competition.

Conclusion

(1) Compared with the DHS D40+, the Nittaku 40 + has a faster rebound speed, higher rebound height, and better dynamic elasticity.
(2) When hitting the Nittaku 40 + ball, players need to actively adjust the timing and increase the power of the stroke to increase the ball speed and spin speed; when serving, players need increase the spin and decrease the rebound height of the ball.

Implication

(1) Compared with DHS D40 + ball, when hitting a Nittaku 40 + ball, players ought to increase the strength to strike the ball forward and increase the range of swing, to ensure the ball successfully cross the net with a suitable arc height and improve the ball speed and spin speed after hitting the ball.

(2) Due to the higher rebound height of Nittaku 40+, it is more difficult for athletes to control the serve quality of the backspin ball, resulting in the weakening of advantage of attack-after-serve tactic, and the chance to win the point in the first three strokes is reduced. In daily training, a targeted training plan can be arranged to improve the players' rally ability, strengthen the transformation ability of attack and defense, enhance the rally ability, and improve the stability of the return quality.
(3) Playing with Nittaku 40 + will increase the rally rounds, extend the match duration, and cost players more fitness energy and strength. Therefore, coaches need to increase the workload of athletes in daily training, strengthen the training of physical fitness, endurance and strength, especially the training of upper limb and waist muscles, so as to improve the strength of athletes' stroke, in order to better cope with the possible long-time and high-intensity competition.

Limitation

(1) This paper only analyzed the dynamic elasticity characteristics and stroke effect of two different brands of new plastic ball, DHS D40 + and Nittaku 40 + respectively. There are several commonly used new plastic ball brands that remain to be studied.
(2) In addition, this paper only took the backhand backspin technique as an example, other defensive and offensive techniques were not covered in this study. Therefore, the findings of this study cannot be applied to other techniques of stroke.

Data availability

The datasets generated during the current study are not publicly available, but are available from the corresponding author upon reasonable request.

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Tian and Wang wrote the main manuscript text. Tian and Xiao performed the data analysis. All authors reviewed the manuscript.

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Declarations

Competing interests
The authors declare no competing interests.

Ethics approval and consent to participate
The ethics committee in Shanghai university of Sport approved this study. All participants was confirmed that this informed and signed consent forms before they joined the study and were provided a full explanation regarding the purpose and potential benefits/risks of the study, confidentiality, and their right to withdraw from the study.

Additional information
Correspondence and requests for materials should be addressed to Y.X.