Comparison of dynamic elasticity between two types of new material plastic table tennis ball: taking DHS D40+ and Nittaku 40+ as an Example

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Abstract

Background: Nittaku 40+ and DHS D40+ are two different brands of new plastic balls, both of which are designated as official match balls and widely used in international events. Due to the change of material and diameter from traditional celluloid table tennis ball to new plastic ball, the hardness and elasticity of the new plastic ball also change accordingly. The purpose of this study is to analyze the difference of the dynamic elasticity between the two brands of new plastic ball, taking Nittaku 40+ ball and DHS D40+ ball as an example.

Method: Self-made experiment was designed to generate different levels of initial speed of table tennis ball to test the dynamic elasticity characteristics of DHS D40+ and Nittaku 40+. A high-speed camera was used to collect the trajectory of ball falling and rebound after hitting the table during the experiment, and the Kinovea software was used 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.

Results: Results showed that the rebound speed and decrement rate of DHS D40+ and Nittaku 40+ both increased with the increase of falling speed, respectively. When falling at slow and medium speeds, there was no significant difference of dynamic elasticity between DHS D40+ and Nittaku 40+. When falling at high speed, there was a significant difference of dynamic elasticity between DHS D40+ and Nittaku 40+.

Conclusion: Compared with the DHS D40+, the Nittaku 40+ has bigger hardness and brittleness, and the sphere structure is more uniform, featuring better dynamic elasticity stability and rebound height.

Introduction

In the past two decades, the International Table Tennis Federation (ITTF) has implemented a series of equipment reform measures, which has generated a profound impact on table tennis events. 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 process, the new plastic balls could be divided into two types, seamed plastic balls and seamless plastic balls [1], both of which are made of ABS material, a ternary copolymer composed of acrylonitrile, butadiene and styrene. ABS material is a kind of engineering plastic, which is mature and widely used featuring stiffness, hardness and toughness. Companies such as Double Happiness from China and Nittaku from Japan have been mass-producing ABS table tennis balls, and these two brands are both designated as official balls in international table tennis events.

There have been a few researches about the comparison of the physical characteristics and stroke effect between the new plastic ball and the traditional celluloid ball. The specific parameters of the new plastic ball and traditional celluloid ball are shown in Table 1.

As the comparison of physical characteristic parameters above, besides the different materials, the biggest difference between the new plastic ball and the traditional celluloid ball lies in the increase of ball diameter. According to the ITTF, the diameter standard of the new plastic ball increased from 39.50 ~ 40.50 mm to 40.00 ~ 40.60 mm [2]. Due to the change of sphere diameter, the volume of the new plastic ball increased by about 16.64% and its weight increased by 8.8% compared with traditional celluloid ball. Thus, the increase extent in volume is bigger than the increase in weight.

The change in table tennis ball material and diameter will directly lead to the change in other physical characteristics, such as hardness and elasticity, thus to affect the stroke effect, such as ball speed, rotation speed, placement and trajectory [3].

Studies show that changes of the ball material and diameter will directly lead to changes in ball's physical properties, such as hardness and elasticity [4]. According to Cheng's research, new plastic ball (seamless) features bigger hardness than traditional celluloid ball [5]. Compared with celluloid ball, the weight increase of new plastic ball results in the faster falling speed after hitting the ball, while the rebound height will be increased as well [5–6]. After hitting new plastic ball and celluloid ball on five different surfaces, results show that the rebound height of the new plastic ball is greater than celluloid ball [7].

The results of the study on the rebound characteristics of new plastic ball show that with the changes of diameter and weight of the new plastic ball, the difference of rebound characteristics between the new plastic ball and the celluloid ball becomes more significant [8]. Due to the different hardness of the ball, the compression deformation caused by the ball hitting the table is different, thus affecting the rebound speed and height of the ball [9].

The change of table tennis elasticity is an important factor that affecting the stroke effect, which includes ball speed, rotation speed, placement and trajectory. In terms of ball speed, the new plastic ball encounters bigger air resistance during the flight because of the increase of ball diameter, causing a drop in ball speed compared with celluloid ball [10]. In addition, the speed decline amplitude of the new plastic ball is found to be greater than the traditional celluloid ball via comparison experiment [11]. What's more, the new seamless plastic ball has greater speed decline amplitude in horizontal than traditional celluloid table tennis ball [12]. In terms of rotation speed, due to the increase of ball diameter and weight, there's slower rotation speed of the new plastic ball than traditional celluloid ball [13]. The experiment results on the placement of new plastic ball and celluloid ball show that the stability and accuracy of the placement of new plastic ball perform better than traditional celluloid ball [5]. When falling rapidly, the decline amplitude of flying trajectory of the new plastic ball presents slower than traditional celluloid ball [6].

To sum up, 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 [8]. The new plastic ball has bigger hardness and higher elasticity than traditional celluloid ball, which will cause the extension of rally duration and add to the intension of the confrontation, and cause less use of the attack-after-serve tactic in competitions [14]. Therefore, players need to increase the stroke power to overcome the impact of air resistance on the ball speed and rotation speed in order to improve the stroke effect [13].

The latest requirements set by the ITTF for ball elasticity detection method is to hold the ball close to a ruler and release it from specific height, so that the ball can drop in free fall, then to measure the elasticity according to rebound height [15]. This method is widely used in equipment quality control before formal table tennis competitions, so as to maximum ensure the fair play. However, although it can detect the ball elasticity, the initial velocity when ball starts to fall is zero [5]. In other words, the detection method is more close to testing the "static elasticity" of table tennis ball, that is, without considering other external force applied on the ball expect the ball gravity. However, in actual training and competition, table tennis ball is hit by players at first, then starts to move at different initial speeds and finally hit the table [16], which causes the situation that the current elasticity detection method doses not completely match the actual application scenario. Therefore, testing the rebound characteristic of ball after hitting the table with different speed levels, which is referred in this study as "dynamic elasticity", has more practical value to guide the actual training and competition of table tennis players.

At present, researches about the ball elasticity mainly focus on the elasticity comparison between new plastic ball and traditional celluloid ball, and most of them are based on the analysis of static elasticity. Now the traditional celluloid ball has been banned and replaced by new plastic ball. However, there are certain differences in the producing mode and quality control of new plastic balls from different companies and brands, which creates the difference in dynamic elasticity of ball. Therefore, it is necessary to study the dynamic elasticity characteristics of new plastic ball manufactured by different brands to provide guidance for the actual training and competition.

The Double Happiness D40+ (DHS D40+) and Nittaku 40 + are two main types of new plastic ball designated for international events [17]. The physical characteristics of both balls such as weight, diameter and rebound height are shown in Table 2. 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 for many times, including the World Championships, Asian Championships, Asian Cup and so on. Therefore, this study designed table tennis dynamic elasticity test device, tested and analyzed the dynamic elasticity characteristics and differences of two different brands of new plastic ball, DHS D40 + and Nittaku40+, to help coaches and athletes make targeted training plan according to different event official ball, to maximum reduce the impact caused by different ball brands, thus to adapt to the match faster and achieve better performance.

Methods

Self-made Experimental Set-up

In this study, the self-made dynamic elasticity experimental device (Figure1) was used to generate different levels of initial speed of table tennis ball to test the dynamic elasticity characteristics of DHS D40+ and Nittaku 40+, two typical brands of new plastic ball. 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 4cm 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 30cm vertically above the circular area. The dynamic elasticity device consisted of a PVC pipe with 8cm 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 the upper end of the PVC pipe to ensure that after applied with initial speed, the test balls could vertically drop and hit the circular target area on the table.

Experimental protocol

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

Data Processing

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

Equation: Rebound Speed Decrement Rate = (Falling Speed - Rebound Speed) / Falling Speed × 100%

The elasticity characteristic and the difference between two brands of new plastic balls was analyzed according to different levels of falling speed and its corresponding rebound speed and rebound speed decrement rate. For the convenience of research, 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), high speed (16 m/s above). The layout of the test device was shown in figure 2.

All statistical analyses were conducted by Statistical Product and Service Solutions (SPSS 22.0, 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 difference of the dynamic elasticity between DHS D40+ and Nittaku 40+. An alpha level of .05 was used to determine statistical significance.

Results

Descriptive Statistics of Dynamic Elasticity

Descriptive statistics analysis was performed on the dynamic elasticity (falling speed, rebound speed, rebound speed decrement rate) of the two types of new plastic ball when falling at three different speed levels.

The Rebound Speed of DHS D40+

The descriptive statistics result of the rebound speed of DHS D40+, when falling at slow, medium, and high speed respectively, was shown in Table 3.

When falling at slow speed, for DHS D40+, the average falling speed was 5.06 m/s, and the maximum falling speed was 10.04m/s. In terms of rebound speed, the average value was 4.47 m/s, the maximum value was 8.29 m/s. When falling at medium speed, the average falling speed was 13.23 m/s, and the maximum falling speed was 14.89 m/s. For rebound speed, the average value was 10.14 m/s, and the maximum value was 10.63 m/s. When falling at high speed, the average falling speed was 23.86 m/s, and the maximum falling speed was 34.34 m/s. In terms of rebound speed, the average value was 12.59 m/s and the maximum value was 15.40 m/s (Table 3).

In the whole dynamic elasticity test experiment, the corresponding curve of the falling speed and rebound speed of the DHS D40+ was shown in Figure 3. In slow falling speed stage, with the increase of elastic potential energy which was generated by the elastic experiment device, the falling speed of ball also increased, while the rebound speed increased accordingly and the speed increase curve trend 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 ($y=0.43x+2.48$). When the falling speed reached to fast level, the rebound speed of DHS D40+ increased steadily along the trend line. However, when the falling speed increased to a certain extent (about 34 m/s in this experiment), the ball began to damage, resulting in a sharp decline in the rebound speed.

The Decrement Rate of Rebound Speed of DHS D40+

In addition, in order to more directly observe the variation of rebound speed decrement rate when falling at different speed levels, the rebound speed decrement rate was calculated according to the formula in the experiment.

The descriptive statistics result of the rebound speed decrement rate of DHS D40+, when falling at slow, medium and high speed respectively, was shown in Table 3.

When the DHS D40+ ball fell at different speed levels, the mean value and maximum value of rebound speed decrement rate both increased according to the increase of falling speed. In the slow speed stage, the average falling speed was 5.06 m/s, and the maximum falling speed was 10.04m/s. In this stage, the average value and maximum value of rebound speed decrement rate was 10.20% and 20.47%, respectively. When falling at medium speed, the average falling speed was 13.23 m/s, and the maximum falling speed was 14.89 m/s. In this stage, the average value and maximum value of rebound speed decrement rate was 23.07% and 29.02%, respectively. In high speed stage, the average falling speed was 23.86 m/s and the maximum falling speed was 34.34 m/s. In this stage, the average value and maximum value of rebound speed decrement rate was 45.75% and 62.39%, respectively (Table 3).

The rebound speed decrement rate also showed a corresponding variation characteristic as the rebound speed in Figure 3. The curve which presented the corresponding relation between falling speed and rebound speed decrement rate of DHS D40+ was shown in Figure 4. In the slow falling stage, with the increase of falling speed, the rebound speed decrement rate increased steadily. When the falling speed came to medium and high level, while the decrement rate still increased in general, the fluctuation amplitude started to intensify and move away from the trend line (y=1.80x+1.54). When the falling speed increased to certain extent (about 34 m/s in this experiment), the test balls started to damage and the decrement rate also increased sharply (Figure 4).

The Rebound Speed of Nittaku 40+

The descriptive statistics result of the rebound speed of Nittaku 40+, when falling at low, medium and high speed respectively, was shown in Table 4.

When falling at slow speed, the average falling speed of the Nitaku 40+ was 6.29 m/s, and the maximum falling speed was 10.91 m/s. Correspondingly, the average value and maximum value of the rebound speed was 5.35 m/s and 8.60 m/s, respectively. When falling at medium speed, the average falling speed was 13.06 m/s and the maximum falling speed was 14.98 m/s. In this stage, the mean value and maximum value of the rebound speed was 11.09m/s and 12.30 m/s, respectively. When falling at high speed, the average falling speed was 21.42 m/s, and the maximum falling speed was 29.30 m/s. Correspondingly, the average value and maximum value of the rebound velocity was 14.06 m/s and 16.05 m/s, respectively (Table 4).

In the whole dynamic elasticity test experiment, the curve of the corresponding relation between falling speed and rebound speed of Nittaku 40+ was shown in Figure 5. 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 ball also increased, while the rebound speed increased accordingly and the speed increase curve trend was relatively stable. When the falling speed increased to medium level, the rebound speed still increased according to the increase of falling speed, but the change of rebound speed began to intensify, moving away from the trend line (y=0.51x+3.09). When the falling speed reached to the fast level, the rebound speed increased steadily along the trend line. When the falling speed increased to certain extent (about 28 m/s in this experiment), the test balls began to damage, resulting in a sharp decline in the rebound speed.

The Decrement Rate of Rebound Speed of Nittaku 40+

The descriptive statistics result of the rebound speed decrement rate of Nittaku 40+, when falling at slow, medium and high speed respectively, was shown in above Table 4.

The results showed that when Nittaku 40+ ball falling at different speed levels, the mean value and maximum value of the rebound speed decrement rate increased with the increase of falling speed. In slow falling speed stage, the mean value and maximum value was 13.27% and 21.21% respectively. In medium stage, the mean value and maximum value was 22.84% and 26.08% respectively. In the high falling speed stage, the mean value and maximum value was 32.29% and 58.24% respectively (Table 4).

The rebound speed decrement rate showed a corresponding variation characteristic as the rebound speed in Figure 5. The curve which presented the corresponding relation between falling speed and rebound speed decrement rate of Nittaku D40+ was shown in Figure 6. When falling at slow speed, the rebound speed decrement rate increased steadily according to the increase of falling speed. In the medium and high speed levels, the rebound speed decrement rate still increased in general, but the fluctuation amplitude intensified and moved away from the trend line ($y=1.39x+3.64$). When the falling speed increased to certain extent (about 28 m/s in this experiment), the test balls started to damage and the decrement rate increased sharply (Figure 6).

Differences of the Dynamic Elasticity between DHS D40+ and Nittaku 40+

The independent t-test was conducted to examine the difference of the dynamic elasticity (falling speed, rebound speed, and the rebound speed decrement rate) between DHS D40+ and Nittaku 40+ when falling at low, medium and high speed respectively.

The Difference of Rebound Speed between DHS D40+ and Nittaku 40+

The results of the difference of the rebound speed between DHS D40+ and Nittaku 40+ was shown in Table 5.

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 high speed level, there was a significant difference of rebound speed between two types of new plastic ball ($p < 0.01$) (Table 5).

In order to more directly observe the change characteristics of the rebound speed of DHS D40+ and Nittaku 40+, the rebound speed curves of the two brands of new plastic ball were compared, as shown in Figure 7. The rebound speed of Nittaku 40+ was faster than DHS D40+ in general. 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 (Figure 7).

The Difference of Rebound Speed Decrement Rate between DHS D40+ and Nittaku 40+

The results of the difference of the rebound speed decrement rate between DHS D40+ and Nittaku 40+ was shown in Table 6.

The results showed that 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 high speed, there was a significant difference of the rebound speed decrement rate between DHS D40+ and Nittaku 40+ ($p < 0.01$) (Table 6).

In order to more directly observe the change characteristics of the rebound speed decrement rate of DHS D40+ and Nittaku 40+, the rebound speed decrement rate curves of the two brands of new plastic ball were put together and shown in Figure 8. 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 ball began to differ, and the rebound speed decrement rate of DHS D40+ was higher than that of Nittaku 40+.

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+ for about 34 m/s, Nittaku 40+ for 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. Reason lied in that the test balls started to damage when falling speed increased to the respective thresholds (Table 7). 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 resistance capacity of 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 7), indicating that the Nittaku 40+ new plastic ball has bigger hardness and brittleness than the DHS D40+ new plastic ball.

Discussion

Since the ITTF banned celluloid ball and replaced with the new plastic ball, a series of researches have been conducted on the physical characteristics and stroke effect of these two different materials table tennis ball. Studies found that the change of material, diameter and weight of table tennis would affect the ball elasticity, and accordingly the elasticity would affect the stroke effect [3]. At present, the 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. The DHS D40 + and Nittaku 40 + are two main official balls designated for the current international events. 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 between DHS D40 + and Nittaku 40+, so as to help athletes and coaches to formulate corresponding techniques and tactics for different competition balls.

In this experiment, the elastic device was designed to apply different initial speeds to test balls. The falling and rebound trajectory of DHS D40 + and Nittaku40 + was collected and calculated to gain the data of average falling speed, rebound speed and decrement rate.

Results showed that when falling at slow and medium speeds, there was no significant difference in the rebound speed and decrement between the DHS D40 + and Nittaku 40+ ($p > 0.05$), respectively. When falling at high speed, there was a significant difference in the rebound speed and decrement rate between DHS D40 + and Nittaku 40 + ball (both $p < 0.01$), respectively. Meanwhile, when the test balls began to damage, the average falling speed of Nittaku 40 + was far smaller than that of the DHS D40+. The reason was that there was bigger hardness of Nittaku 40 + than DHS 40+, so that the falling speed threshold where the test balls began to damage was less than that of DHS D40+.

Moreover, in fast falling stage, the average value of rebound speed decrement rate of Nittaku 40 + was much smaller than DHS D40+. What's more, 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 the energy wastage in the motion process is smaller, so the rebound speed decrement rate is relatively lower, and the rebound speed presents higher, correspondingly showing higher rebound height [11] (Fig. 6).

At the same time, the rebound speed decrement rate of both brands of new plastic ball increased with the increase of falling speed. In the slow and medium speed stages, the rebound speed decrement rate of DHS D40 + and Nittaku 40 + was not significantly different, and the decrement rate curve fluctuated slightly along the trend line. In the high speed stage, the decrement rate of the two brands of new plastic ball began to show difference that the DHS D40 + had higher value than that of Nittaku 40+. Therefore, when these two different brands of new plastic ball hit the table at the same falling speed (high speed level), the rebound speed wastage of Nittaku 40 + was smaller, resulting in bigger rebound speed and higher rebound height, compared with DHS D40+. This is because the internal structural characteristics of Nittaku 40+. Nittaku 40 + sphere structure 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, so that the energy wastage is smaller, thus to produce perform higher rebound height and make Nittaku 40 + present better dynamic elasticity than DHS D40+.

At the same time, the experiment also found that when the falling speed increased to certain extent (DHS D40 + for about 34 m/s, Nittaku 40 + for about 28 m/s), the rebound speed decrement rate of the two different brands of new plastic ball both sharply increased. This was because the DHS D40 + and Nittaku 40 + sphere began to damage at their respectively falling speed thresholds, and the two brands of new plastic ball shared different damage characteristics. 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+.

Comprehensively analysing, the difference in the dynamic elasticity between DHS D40 + and Nittaku 40 + new plastic ball is mainly due to the different manufacturing process and sphere structure. Nittaku 40 + has bigger hardness than DHS D40+, and DHS D40 + is relatively soft. So when the two brands of new plastic ball are applied with the same initial speed to hit the table, the DHS D40 + has more deformation and bigger contact area with table than Nittaku 40+, leading to slower rebound speed than Nittaku 40+, so the ball damage falling speed threshold of DHS D40 + also is higher. The differences above will inevitably influence the athletes’ techniques and tactics application in their daily training and competition.

Firstly, for serve technique, due to the bigger hardness, brittleness and rebound speed of Nittaku 40+, 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 [11]. 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+.

Secondly, 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. 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 [1].

Finally, compared with the DHS D40+, when playing with Nittaku 40 + new plastic ball, the number of rally increases and the overall match duration extends. At the same time, before the ball damages and the ball speed sharply declines, 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.

Conclusions

(1) The new plastic ball has bigger weight and diameter than traditional celluloid ball. The ball hardness and rebound ability are better than traditional celluloid ball as well.

(2) The rebound speed and decrement rate of DHS D40 + and Nittaku 40 + both increase with the increase of falling speed, respectively.

(3) When falling at slow and medium speeds, there is no significant difference of dynamic elasticity between DHS D40 + and Nittaku 40+. When falling at high speed, there is a significant difference of dynamic elasticity between DHS D40 + and Nittaku 40+.

(4) Compared with the DHS D40+, the Nittaku 40 + has bigger hardness and brittleness, and the sphere structure is more uniform, featuring better elasticity stability and rebound height.

Implications

(1) When falling at high speed, there is a significant difference of the dynamic elasticity between DHS D40 + and Nittaku 40+, which requires professional athletes, especially players in national teams, to adapt to the characteristics of the event official ball, thus to make related training and tactic schedule.

(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.

Limitations

(1) This paper only analyzed the dynamic elasticity characteristics 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 this paper, the dynamic elasticity characteristics of DHS D40 + and Nittaku 40 + were discussed, but the influence of the difference in dynamic elasticity characteristics on athletes' techniques, tactics and stoke effect was not covered, which could be analyzed in future research.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

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

Competing interests

The authors declare that they have no competing interests.

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Author Contributions

All authors read and approved the final manuscript. Conceptualization, Y.X.; Methodology, Y.X. and Z.W.; Tool, Y.X.; Data analysis, Y.X., Z.W. and Y.Z.; Writing-original draft preparation, Y.X., Z.W., Y.Z. and J.T.; Writing-review and editing, Y.X. and Z.W.; Supervision, Y.X.

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References

1. Zhang, M. Y., & Xu, J. L. (2014). Development and application prospect of non-celluloid table tennis technology. Journal of Hebei Institute of Physical Education, 28 (4), 60–64.
2. Küneth, T. (2017). The new plastic balls; questions and answers. Unpulished paper. Equipment Committee, International Table Tennis Federation.
3. Xu, J. W. (2018). Study on Tactical Ability of Elite Athletes after Implementation of New Plastic Table Tennis. Journal of Beijing University of Sport (10),118–124 + 132.
4. Zhong, Y. C. (2016). The impact of the use of new material seamless balls on the development of table tennis. Caizhi, (18), 250.
5. Cheng, B. J., & Yang, H. (2014). Experimental study of the characteristics and the influence of the ball speed and rotation. Journal of Beijing University of Sport, (10), 5.
6. Inaba, Y., Tamaki, S., Ikebukuro, H., Yamada, K., Ozaki, H., & Yoshida, K. (2017). Effect of changing table tennis ball material from celluloid to plastic on the post-collision ball trajectory. Journal of human kinetics, 55, 29.

7. Chen, Y. F., & Huang, C. C. (2020). Performance Effects of Different Table Tennis Ball Materials. Smart Science, 8(2), 84–94.
8. Iimoto, Y., Yoshida, K., & Yuza, N. (2002). Rebound characteristics of the new table tennis Ball; Differences between the 40 mm (2.7 g) and 38 mm (2.5 g) balls. Int J Table Tennis Sci, 5, 233–243.
9. Chen, X. H., & Li, Y. G. (1995). Discussion on the increment of rebound speed after the topspin falls. Zhejiang Sports Science, (05).
10. Kawazoe, Y., & Suzuki, D. (2004). Comparison of the 40 mm ball with the 38 mm ball impacted to the table tennis racket based on the predicted impact phenomena. Science and racket sports III, 140–145.
11. Xiao, Y., Huang, R., Ren, J., & Li, T. J. (2019). Experimental study on elastic characteristics of new seamed and seamless plastic table tennis balls and their effects on hitting speed and spin. Journal of Tianjin Institute of Physical Education, (1), 67–73.
12. Meyer, D., & Tiefenbacher, K. (2012). Comparison of plastic ("poly") and celluloid balls; evaluation of difference for rebound on racket and player perception. Unpublished report. Equipment Committee, International Table Tennis Federation.
13. Lee, M. J., Ozaki, H., & Goh, W. X. (2019). Speed and spin differences between the old celluloid versus new plastic table tennis balls and the effect on the kinematic responses of elite versus sub-elite players.
14. LIJin-liang, ZHAOXia, & ZHANGChao-hui. (2005). The technical changes and development brought about by the new rules to table tennis. Sports Science and Technology, 26(3), 4.
15. The ITTF Quality Programme for Balls (https://documentstore.ittf.com/documents/M3%20BALL%20MANUAL%20rev1%20BoD2021.pdf).
16. Cheng, B. J. (2014). Preliminary study on the characteristics of new seamless plastic table tennis and the influence of technology and tactics. China Sports Science and Technology, 50 (05), 68–72.
17. Equipment Committee of International Table Tennis Federation. Ball equipment approval handbook. Available at: https://equipments.ittf.com/#/equipments/balls.
18. LION 31st ITTF-ATTU Asian Cup Yokohama 2018(https://www.ittf.com/wp-content/uploads/2018/03/Prospectus_2018-Asian-Cup-20180328.pdf).
19. Lu, Y. Y. (2018). A review of plastic table tennis research. Sporting Goods and Technology (12), 26–27.
20. Nagurka, M. (2003). Aerodynamic effects in a dropped ping-pong ball experiment. International Journal of Engineering Education, 19 (4), 623–630.
21. The Double Happiness (http://www.dhs-sports.com/malong/).
22. SSP 24th ITTF-Asian Table Tennis Championships 2019(https://ittf.cdnomega.com/eu/2019/04/Prospectus_ATTC.pdf).
23. 2017 Asian Table Tennis Championships(https://www.ittf.com/wp-content/uploads/2017/01/ATTC_2017_Prospectus_v3.4.2.pdf).

24. 2017 world table tennis championships (https://www.ittf.com/wp-content/uploads/2016/11/Prospectus_WTTC2017.pdf).

Tables

Table 1. Comparison of physical characteristics between the new plastic ball and celluloid ball

Characteristic / Type	New Plastic Ball	Celluloid Ball
Material	ABS	Nitrocellulose
Weight /g	2.72～2.75	2.69～2.76
Diameter / mm	40.00～40.60	39.50～40.50
Elasticity / ($mm \cdot mm^{-1}$)	240～260/300	256～260/300
Hardness / mm	Depth after pressing top and bottom is 0.77～0.82, and depth after pressing ball seam spot is 0.76～0.81.	Depth after pressing top and bottom is 0.69～0.81, and depth after pressing ball seam spot is 0.72～0.83.

Table 2. Comparison of Physical Characteristics between DHS D40+ and Nittaku 40+

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

Table 3. Descriptive Statistics of Dynamic Elasticity of DHS D40+

Falling Speed Level	Speed Category	Min	Max	M±SD
Slow	Falling Speed/$m\cdot s^{-1}$	2.02	10.04	5.06±2.28
	Rebound Speed/$m\cdot s^{-1}$	1.97	8.29	4.47±1.84
	Decrement Rate/%	2.63	20.47	10.20±4.39
Medium	Falling Speed/$m\cdot s^{-1}$	11.33	14.89	13.23±1.36
	Rebound Speed/$m\cdot s^{-1}$	9.34	10.63	10.14±0.62
	Decrement Rate/%	17.56	29.02	23.07±4.27
High	Falling Speed/$m\cdot s^{-1}$	15.30	34.34	23.86±5.54
	Rebound Speed/$m\cdot s^{-1}$	10.41	15.40	12.59±1.48
	Decrement Rate/%	29.34	62.39	45.75±7.14

Table 4. Descriptive Statistics of Dynamic Elasticity of Nittaku 40+

Falling Speed Level	Speed Category	Min	Max	M±SD
Slow	Falling Speed/$m\cdot s^{-1}$	2.46	10.91	6.29±2.89
	Rebound Speed/$m\cdot s^{-1}$	2.19	8.60	5.35±2.12
	Decrement Rate/%	5.39	21.21	13.27±5.58
Medium	Falling Speed/$m\cdot s^{-1}$	11.19	14.98	13.06±1.27
	Rebound Speed/$m\cdot s^{-1}$	9.12	12.30	11.09±1.00
	Decrement Rate/%	17.16	26.08	22.84±2.79
High	Falling Speed/$m\cdot s^{-1}$	15.20	29.30	21.42±4.41
	Rebound Speed/$m\cdot s^{-1}$	12.24	16.05	14.06±1.12
	Decrement Rate/%	21.05	58.24	32.29±9.56

Table 5. Difference of Rebound Speed Between DHS D40+ and Nittaku 40+ (m/s)

Falling Speed Level	DHS D40+ （M±SD）	Nittaku 40+ （M±SD）	z-value	p-value
Slow	4.47±1.84	5.35±2.12	-1.655	0.098
Medium	10.14±0.62	11.09±1.00	-1.852	0.064
High	12.59±1.48	14.06±1.12	-3.359	0.001**

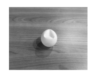
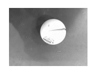
*Note: * p<0.05,** p<0.01*

Table 6. Difference of Rebound Speed Decrement Rate between DHS D40+ and Nittaku 40+ (%)

Falling Speed Level	DHS D40+ （*M±SD*）	Nittaku 40+ （*M±SD*）	*z-value*	*p-value*
Slow	10.20±4.39	13.27±5.58	-1.910	0.056
Medium	23.07±4.27	22.84±2.79	0.000	1.000
High	45.75±7.14	32.29±9.56	-4.641	0.000**

*Note: * p<0.05,** p<0.01*

Table 7. Comparison of Ball Broken Status between DHS D40+ and Nittaku 40+

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

Figures

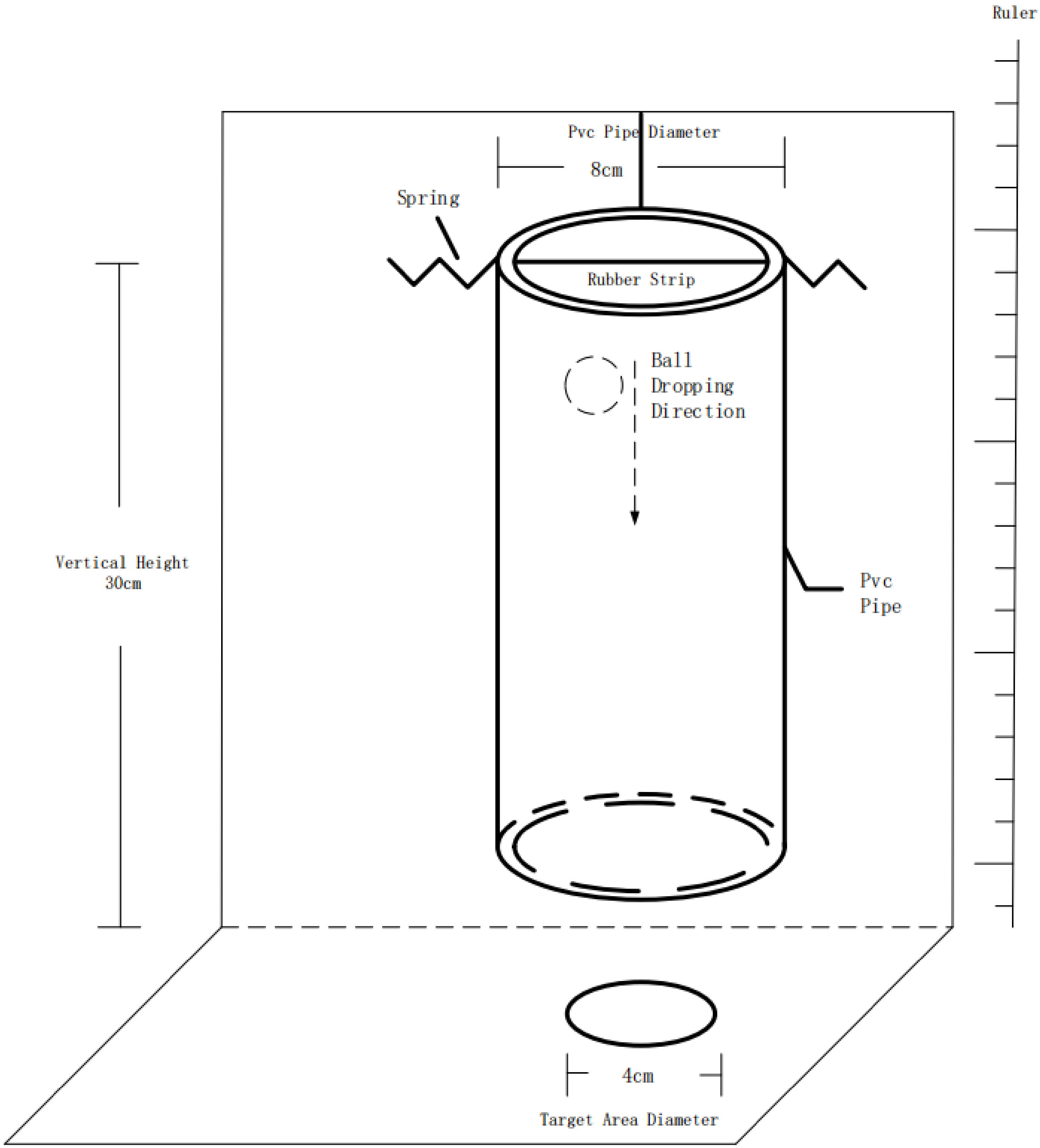


Figure 1

Self-made Dynamic Elasticity Experimental Set-up

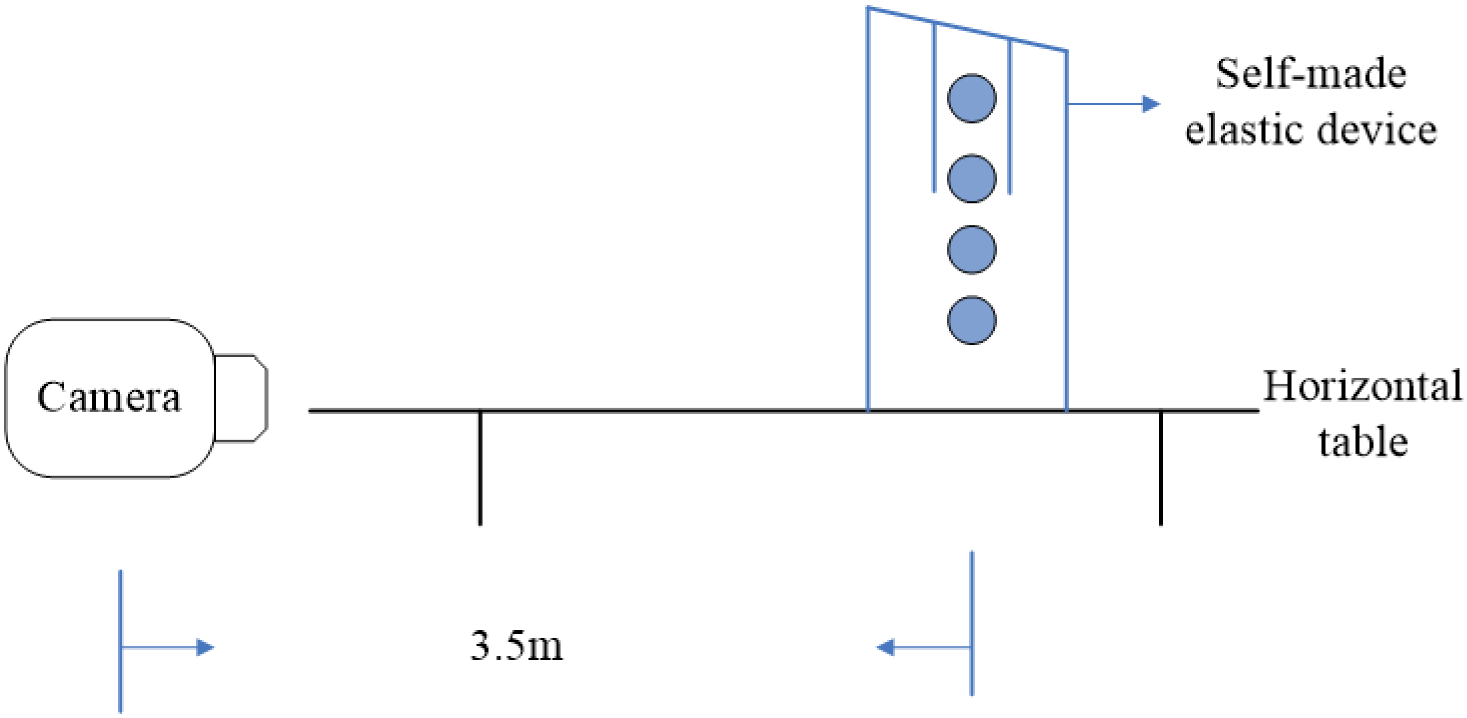


Figure 2

Schematic Diagram of Equipment Layout of Test

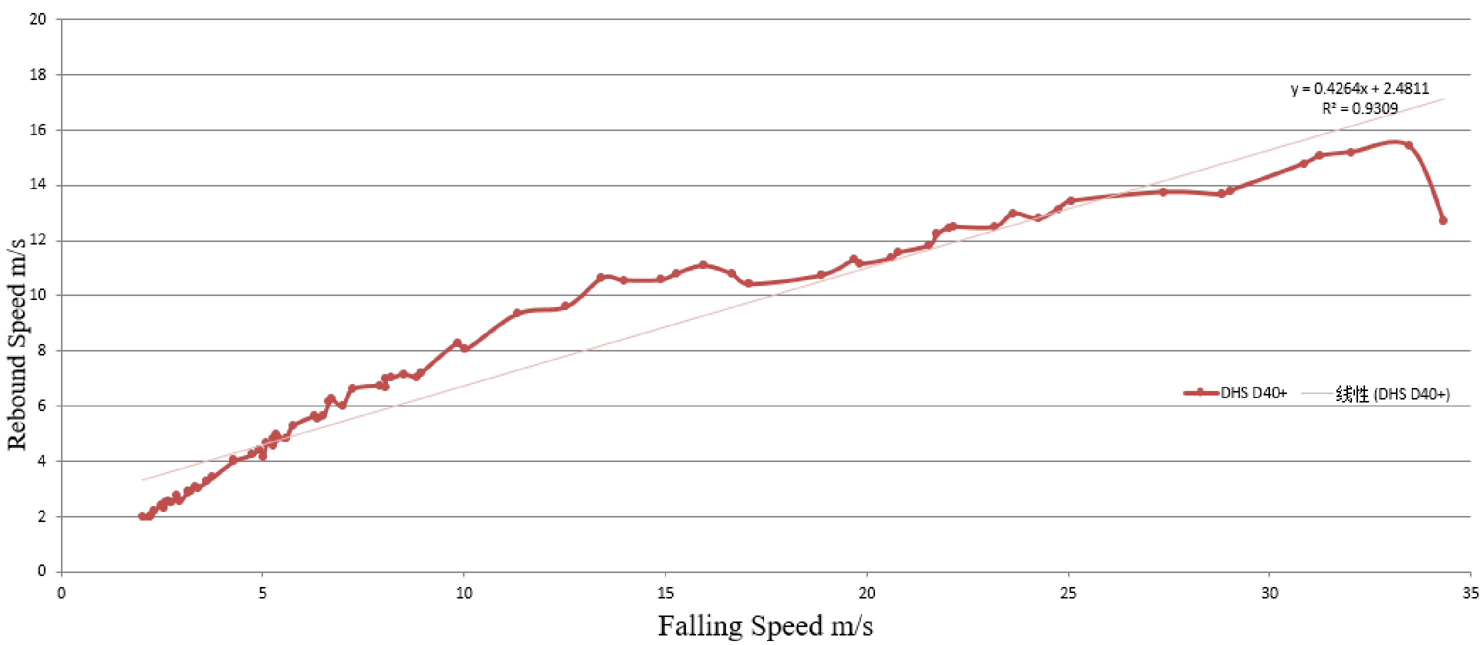


Figure 3

Rebound Speed Curve of DHS D40+

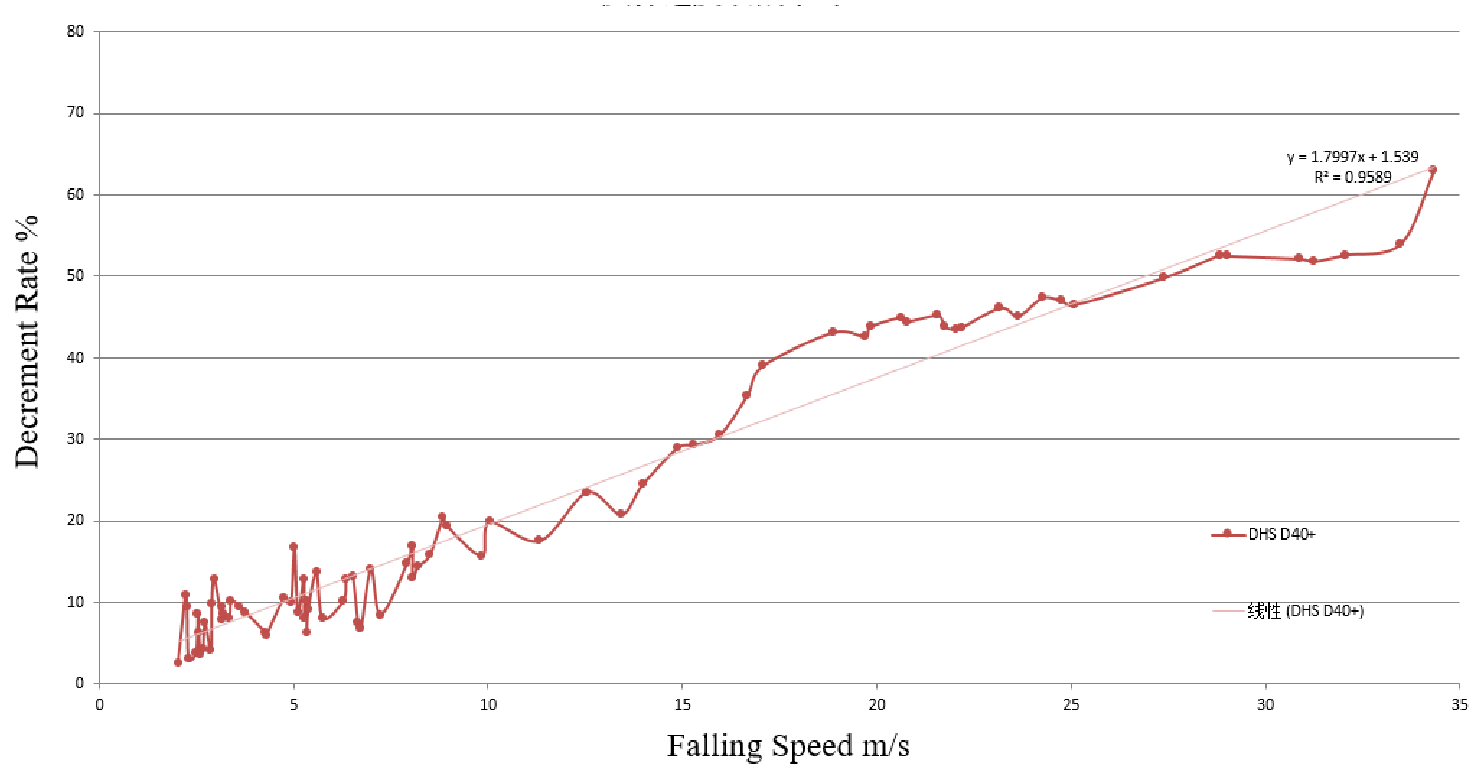


Figure 4

Curve of Rebound Speed Decrement Rate of DHS D40+

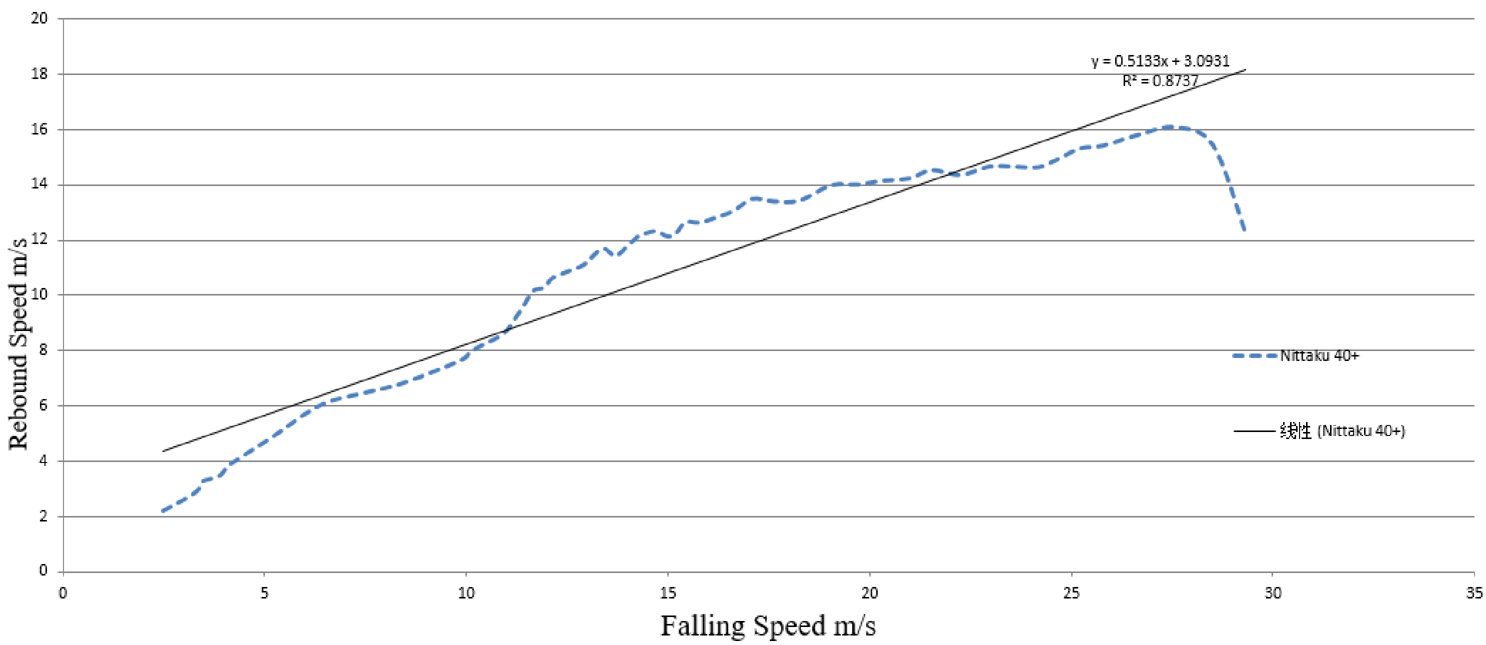


Figure 5

Rebound Speed Curve of Nittaku 40+

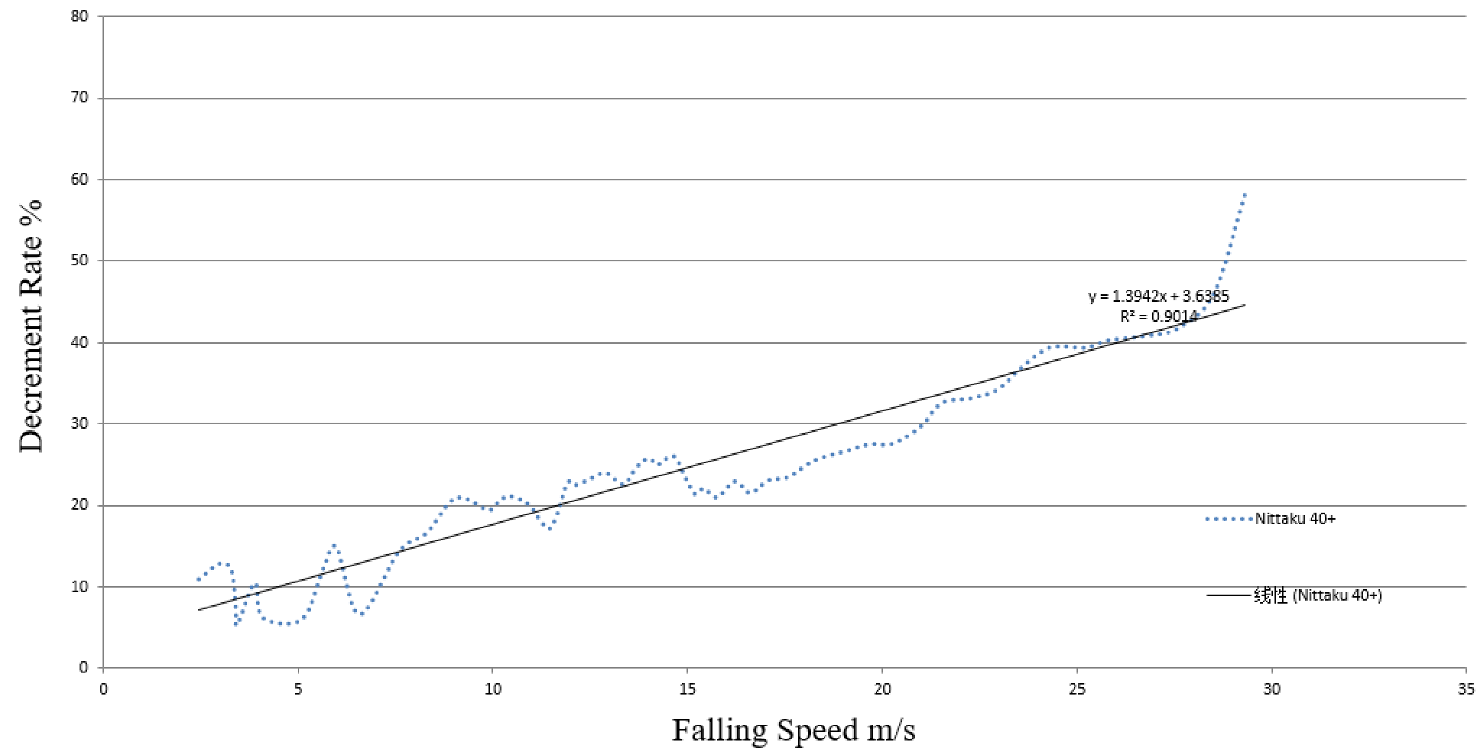


Figure 6

Curve of Rebound Speed Decrement Rate of Nittaku40+

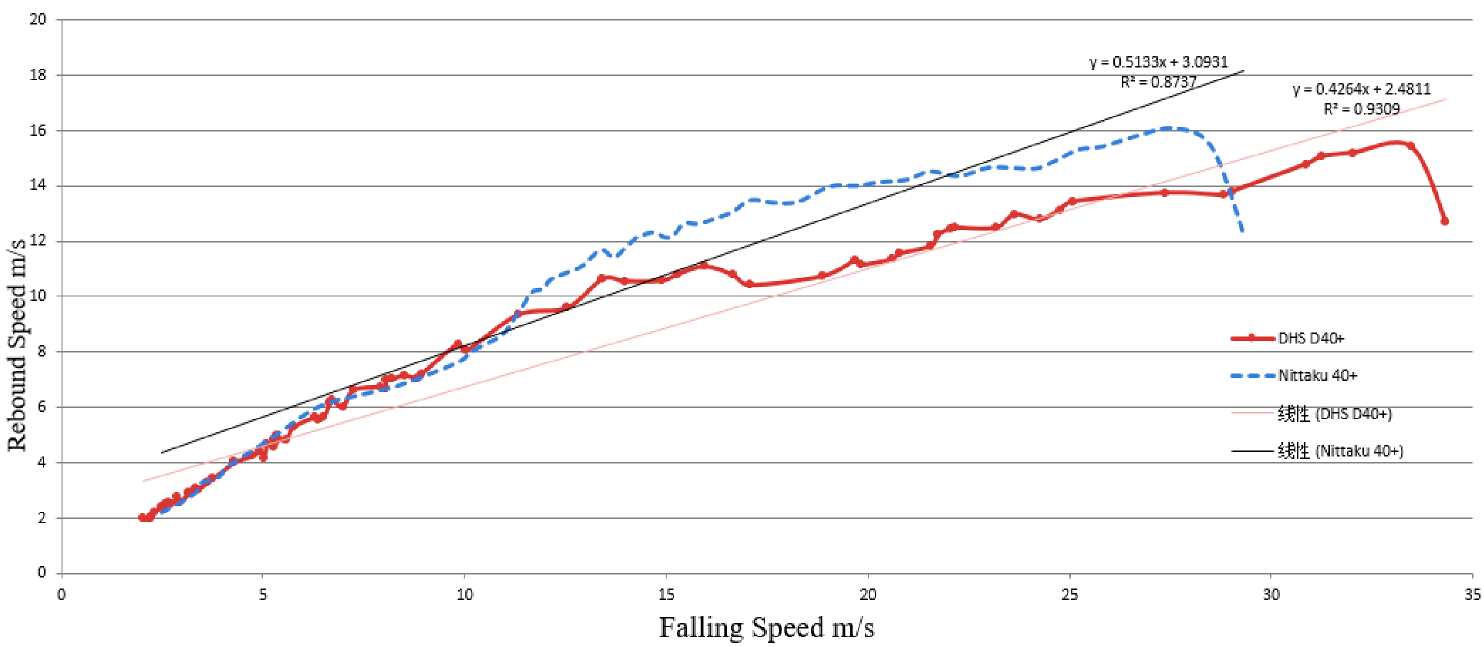


Figure 7

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

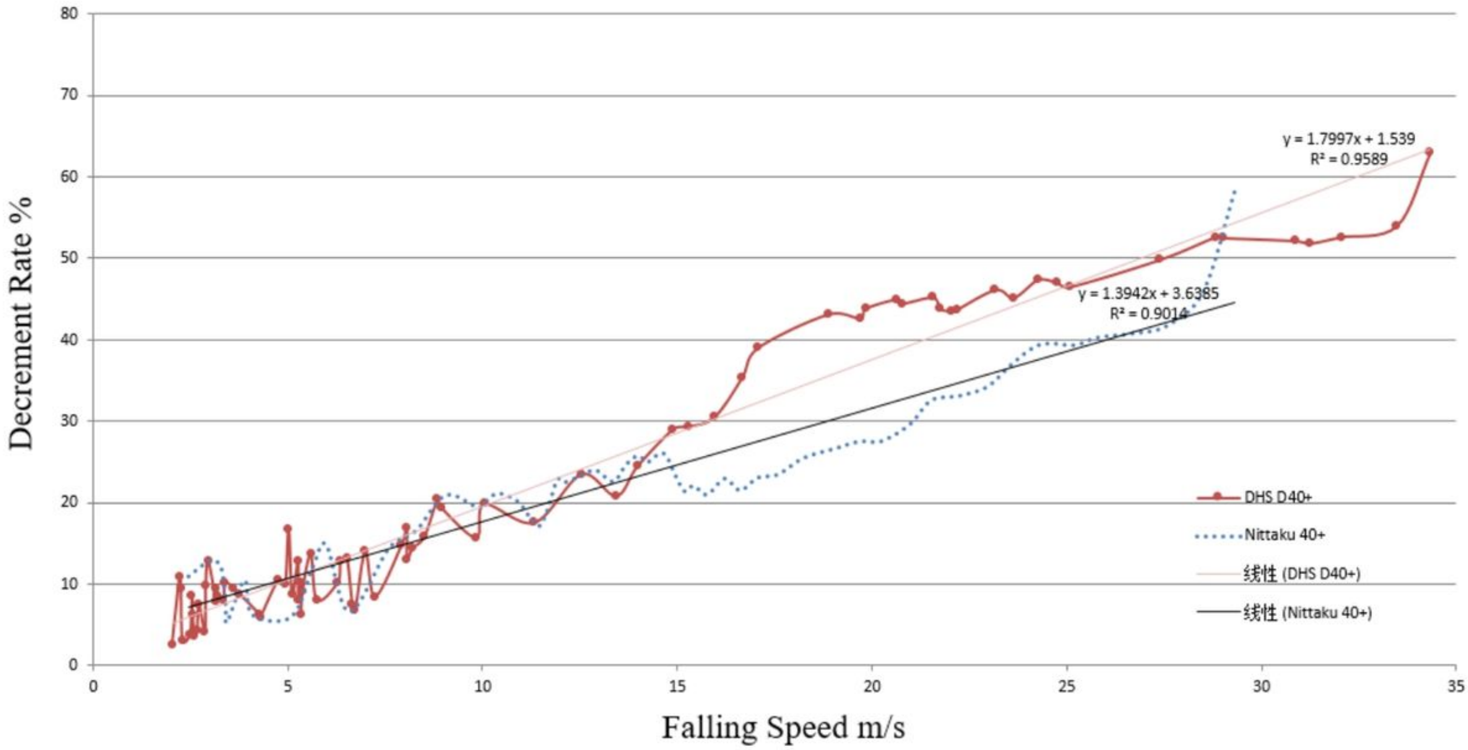


Figure 8

Comparison of the Curve of Rebound Speed Decrement Rate Between DHS D40+ and Nittaku 40+