Shuttlecock Velocity of a Badminton Drop Shot

Ampharin Ongvises and Xiaoyu Xu

Abstract

In a badminton 'drop shot', the shuttlecock is struck by a non-rotating racquet at low speed. In this investigation, a shuttlecock was hit by a badminton racquet in a linear collision, simulating a drop shot. The collision was recorded with high-speed video and the velocities of the racquet and shuttlecock determined. The relationship between the impact velocity of the racquet and the velocity of the shuttlecock as it leaves the badminton racquet after collision was found to be proportional over the range tested.

Introduction

In badminton, one variation of the 'drop shot' involves the player, in a linear motion, gently 'push' the shuttlecock using the racquet to give it enough speed for it to travel just over the net and into the opponent's court. This type of shot is different from a smash as the pivot motion of the racquet head relative to the hand is greatly reduced, or even eliminated, and the velocities of the racquet and the shuttlecock are much lower. For this type of shot, the relationship of the velocity of the racquet and the velocity of the shuttlecock between the racquet and the shuttlecock is particularly important, as it is essential to predict the trajectory of the shuttlecock. This research will investigate the relationship between the impact velocity of the racquet and the velocity of the shuttlecock as it leaves the racquet over a normal range of drop shot velocities.

In a drop shot, there are a number of factors affecting the shuttlecock velocity: the impulse of the hand on the racquet during the impact, the elasticity of the collision, and the change in momentum of the racquet during the collision. The following equation models the collision,

$$J_{hand} + (m_{rq}\overrightarrow{V_{rqi}} - m_{rq}\overrightarrow{V_{rqf}}) = m_s\overrightarrow{V_s} \tag{1}$$

where J_{hand} is the impulse of the hand during the collision, m_{rq} is the effective mass of the badminton racquet, m_s is the mass of the shuttlecock, V_s is the velocity of the shuttlecock, V_{rqi} is the initial velocity of the badminton racquet and V_{rqf} is the final velocity of the badminton racquet. If the elasticity of collision is constant and the impulse of the hand is proportional to initial racquet speed, the initial racquet head velocity is expected to be proportional to the shuttlecock velocity. Also, if the impulse of the hand on the racquet during the collision is proportional to the initial velocity of the racquet, then the shuttlecock velocity is predicted to be proportional to the initial velocity of the racquet.

The conditions of this investigation are similar to those of a paper published in the ISB Journal of Physics, where Pirapong Jitngamplang investigated 'the relationship between the impact speed of a putter head and the resulting velocity a golf ball' in golf putting.[1] This paper, like the current investigation, involved a hand applying an impulse on a head via a long elastic shaft while the head strikes a smaller object, a golf ball or a shuttlecock. Jitngamplang found that the initial velocity of the golf ball was directly proportional to the impact velocity. A similar relationship is expected between the impact velocity of the badminton racquet head and the velocity of the shuttlecock in a drop shot.

Method

The shuttlecock was hung with its cone pointing vertically downward using a pin attached to its cork, as shown in Figure 1. The Casio EX-F1 camera was set to record at 1200 frames per second, with a resolution of 336 × 96 pixels. For each trial the racquet was gently pushed upward, hitting the shuttlecock in a linear collision. A series of hits with racquet speeds over the normal range of drop shots was recorded.

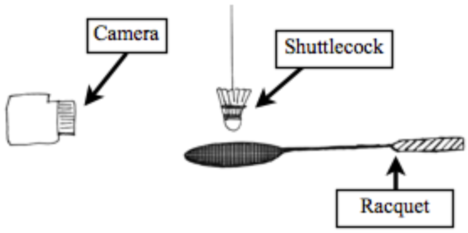

Figure 1 Setup used during the investigation.

The racquet used was a Yonex® Nanoray 500 with a mass of 91.00g (±0.05g). The string was Yonex® BG66 Ultimax string with a tension of 23lb (±0.5lb). The shuttlecock was a Yonex® Aeroclub TR feathered shuttlecock with a mass of 5.10g (±0.05g) (with pin). The room temperature was 27°C (± 1°C).

Logger Pro® Video Analysis was used to determine the initial and final velocities of the badminton racquet and the shuttlecock in 20 trials with the racquet velocities ranging from 0.02m/s to 0.05m/s. For each trial, the 50 frames before and after the collision was analyzed to minimize the effect of gravity on the data collected. The analysis process involves, for each trial tracking on one spot of the racquet for the 50 frames prior to impact and the same for the shuttlecock for the 50 frames after impact, as shown in Figure 2, with the velocities being calculated accordingly.

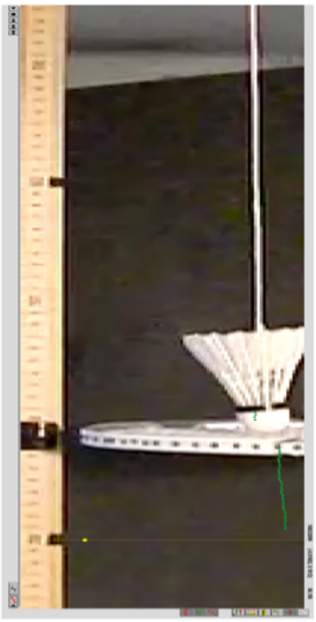

Figure 2 Sample video clip. The green dots represent the position of the shutlecock and racquet in each frame.

Results and Discussion

The results of the experiment, as shown in figure 3, show that there is a proportional relationship between impact speed of the racquet and the resulting shuttlecock speed for a badminton drop shot,

$$V_s = (1.35 \pm 0.03) V_{rqi} \tag{2}$$

Equation 2 suggests that the velocity of the shuttlecock as it leaves the racquet face will be 1.35 times the impact velocity of the racquet. Thus, if badminton players want to increase the speed with which the shuttlecock leaves their racquet, they only have to increase the impact speed of the racquet, knowing that the shuttlecock speed will increase proportionally.

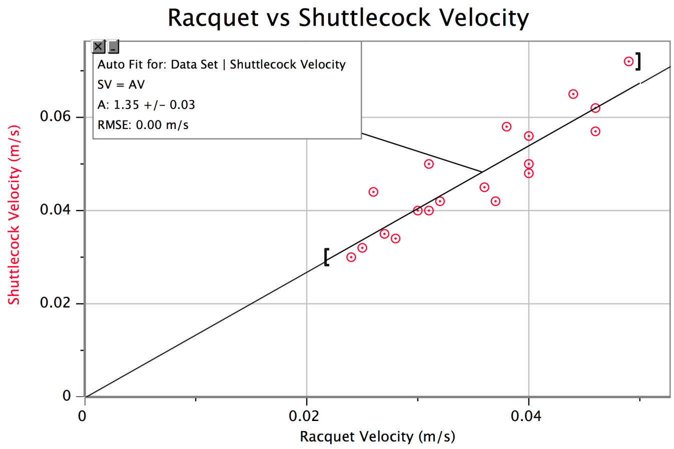

Figure 3 The velocity of the racquet against the velocity of the shuttlecock, showing a proportional relationship.

The final equation is consistent with Equation 1, which predicted that shuttlecock velocity would be proportional to initial racquet velocity if the impulse of the hand on system during collision was proportional to racquet speed.

The results of this investigation are similar to Jitngamplang's paper,[1] which concluded that the initial velocity of the golf ball was proportional to impact speed of the putter head. However, the proportionality constant between the initial velocity of a badminton shuttlecock and impact speed was found to be lower than the golf ball's, with the initial velocity of a golf ball being 2.03 times the impact velocity while the initial velocity of the badminton shuttlecock was found to be only 1.35 times the impact velocity. Further research is suggested to investigate the reason for this difference.

The distribution of the points in Figure 3 shows there is some variation in the relationship between racquet impact velocity and shuttlecock velocity. This was most likely due to the fact that there was some variation in the impact point on the racquet head. This would have changed the nature of the interaction, and thus the relationship studied, since the tension of the racquet string varies at different places on the racquet.

For further investigation, a wider range of badminton racquets, types of strings, string tensions and impact points on the racquet could be tested. A variety of different badminton shuttlecocks could also be used to investigate which would produce greater velocities.

Conclusion

For a badminton drop shot, the relationship between racquet impact velocity and the velocity of the shuttlecock as it leaves the racquet face is shown to be proportional. Under the conditions investigated, it was shown that on average the velocity of the shuttlecock was 1.35 times the impact velocity. This relationship is similar to that found in putting a golf ball.

References

[1] Jitngamplang, Pirapong. (2009). Velocity of a Golf Putt. ISB Journal of Physics, 3(2). Retrieved from http://www.isb.ac.th/HS/JoP/vol3iss2/Papers/1Putting.pdf.