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Coefficient of Restitution of Wet Tennis Balls

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Abstract

The coefficient of restitution of a damp tennis ball is of interest to tennis players. Using a spray bottle, water was added to a tennis ball and the mass of water on the wet ball was determined. The ball was then dropped from a fixed height of 0.86 m. The motion was recorded with a video camera and the bounce height was measured. Using the bounce height and the original height, the coefficient of restitution for that mass of added water was determined. The research found the mass of water added to the tennis ball to have a negatively linear relationship with the coefficient of restitution of the tennis ball.

Introduction

In 1925, a rule defining the bounce height of a regulation ball was set by the International Tennis Federation (ITF). This rule is still in force today. According to the rule, the tennis ball should bounce to between 135 cm and 147 cm above the floor level when dropped from a height of 254 cm.[1] This rule is for standard, dry conditions.

When a ball is bounced off the floor, the Coefficient of Restitution (COR) is defined as "The ratio of speed of separation to speed of approach in a collision."[2] The Coefficient of restitution is used to quantify how well a ball bounces.[3] Assuming conservation of energy while the ball is in the air, this can be shown to be equal to the square root of the ratio between initial drop height and the height after a bounce:

$$COR = \sqrt{\frac{h_{after}}{h_{initial}}} \tag{1}$$

where h_{after} is height of the tennis ball after a bounce and $h_{initial}$ is the height of the tennis ball before the bounce.

While the COR for a regulation tennis ball is clearly defined, tennis is often played in mist or light rain conditions, which will make the tennis ball wet. So the question arises: Is the COR still the same when the tennis ball is wet? The relationship between the mass of water sprayed onto a tennis ball and its coefficient of restitution was investigated in this research. Knowing the bounce height under different conditions is important because players will be able to adjust their posture to hit the ball correctly.

Methods

To create a wet ball, water was sprayed evenly around a new Wilson Titanium tennis ball with dry mass of 55.85 ± 0.01g, using a spray bottle. The wet ball was then massed. A bar was fixed at the initial height at which the ball would be dropped. A digital camera was set up facing parallel to the ground so that it could video the entire bounce. A meter stick was fixed to a stand next to the dropping point and perpendicular to the ground to be used as a reference length. The ball was filmed as it was dropped from a height of 0.86 ± 0.005m. Using Logger Pro video analysis, the position of the ball at its dropping point and the peak point after the bounce were determined. After each bounce, the ball was sprayed to restore it to its initial mass for that set of trials. Every trial was conducted at a temperature of 25 ± 0.5ºC. Wetness levels from the dry ball up to the wet ball with mass of 68.90 g were tested.

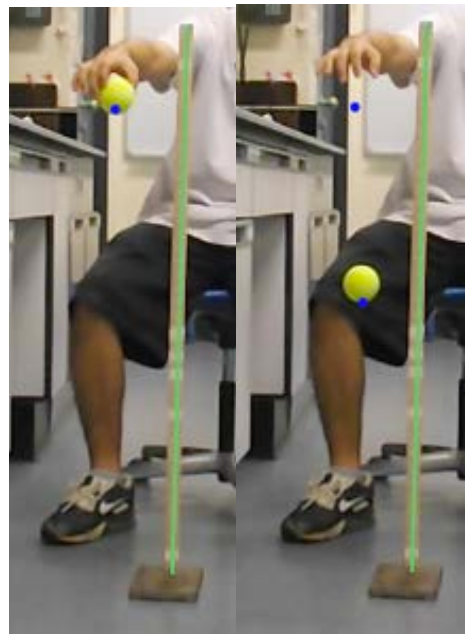

Figure 1 The captured frames of the ball at its dropped height and bounced height.

Results and Discussion

In figure 2, the relationship between the coefficient of resolution of the tennis ball and the added mass of water is:

$$COR = (-0.0025\ g^{-1})m + 0.78 \tag{2}$$

where m is the mass of the added water in grams. The results show a negative linear relationship between the coefficient of restitution and the mass of added water. Adding a gram of water decreases the coefficient of restitution of a tennis ball by approximately 0.0025. A ball that bounces to a median 140 cm when dropped from the standard drop height of 254 cm is expected to be reduced to the regulation limit of 135 cm with the addition of 5 g of water, and will only bounce to 128 cm when saturated, with 13g of added water. In terms of effect on gameplay for tennis players who are accustomed to the regulation coefficient of restitution, a wet ball with a decreased coefficient of restitution might make players incorrectly predict the trajectory of the wet ball after the bounce, making it more difficult to hit. The addition of water on the tennis ball can, therefore, have an effect on the game. As shown, the addition of 5g of water causes a reduction of bounce height of only 5cm , while the regulation allows a maximum range of 12cm difference in bounce height. This suggests that small amounts of water will not cause the bounce of the tennis ball to be out of regulation range.

A point to be noted is that the full range of dampness, from dry to dripping wet, was investigated here. Considering that a tennis ball in active play would typically have only small amounts of water on it, it is suggested that further work be done investigating more fully the range from 0 g to 3 g of added water.

It is expected that all tennis balls will behave similarly, although the effect of dampness might be slightly different for different brands. Research investigating the effect of dampness on a range of tennis balls from a range of drop heights is suggested.

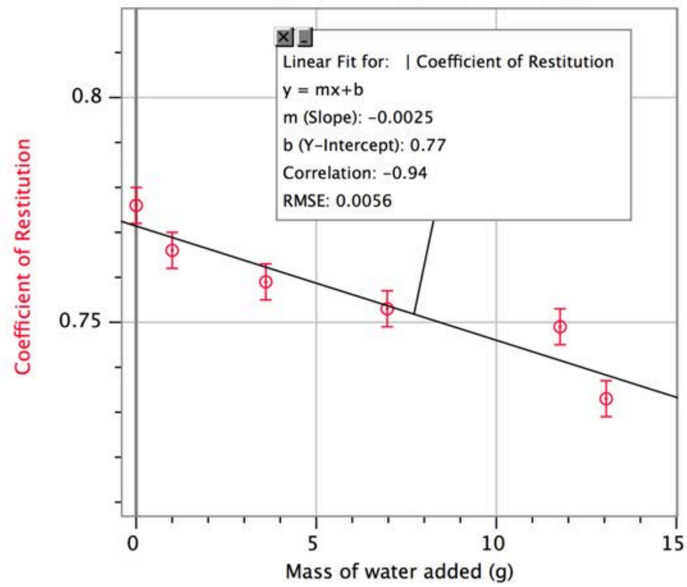

Figure 2 A negative linear fit showing the relationship of Coefficient of Restitution and the mass of water added to the tennis ball.

Conclusion

It has been shown that the coefficient of restitution of wet tennis balls decreases linearly with the addition of water. Wet tennis balls do not bounce as well as dry ones. For the Wilson Titanium tennis balls tested in this research, the coefficient of restitution was shown to decrease by 0.0025 per gram of added water.

References

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