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Aerodynamic and Kinematic Factors Governing Slice (Backspin) Drop Shot Performance in Lawn Tennis

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Abstract
This study derives a proportionality and linear relation between launch speed (m/s) and racket angle (degrees). The strokes considered were solely slices, with the range of theta and bounce generation being the sole differentiations. For a shot to be a success, it must produce minimal bounce, while still traversing the net (~ 0.91 m) and landing between 12.5-13.25 m. After data collection of 15 trials under consistent conditions, the values were used to generate a regression model, $u = 23 - 0.46\theta$ and mathematical modelling and projectile equations were utilised to obtain the following empirical equation. These results were obtained whilst keeping the Magnus effect of spinning bodies and fluid drag strictly in mind. This demonstrates a strong linear relation between launch speed and racket angle, with each degree of increase in racket angle indicating a reduction in launch speed by a factor of ~ 0.46 m/s.

INTRODUCTION

As dropshots change the pace of professional and recreational rallies worldwide, they have captured attention for their demanding skill and precision, for they require accurate control of ball speed, spin, and trajectory- unlike conventional groundstrokes. This study aims to fill the gap in the analysis of slice drop shots, with specialised attention to the angle and speed for an optimum stroke.

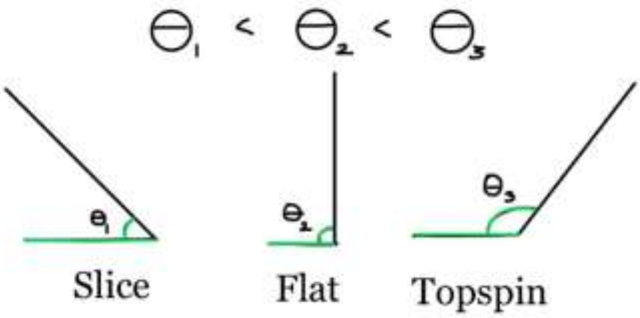
The trajectory of a tennis ball during a drop shot is influenced by several aerodynamic and mechanical factors, including gravity, air resistance, and spin.

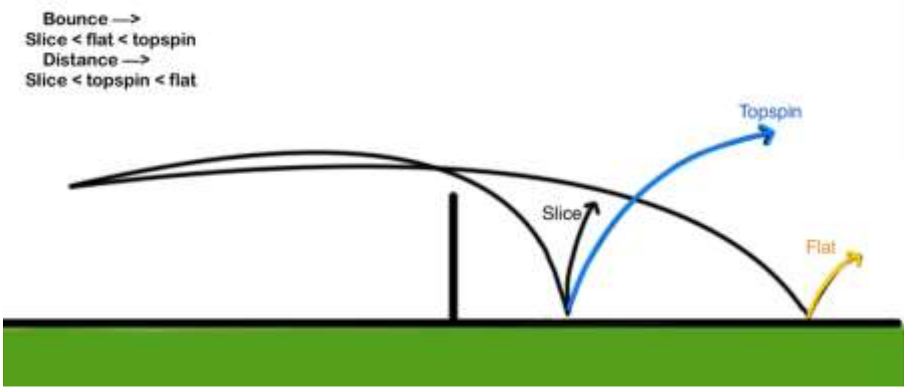
1. Gravity - downward acceleration
2. Drag (air resistance) - reduction of horizontal velocity
3. Magnus effect - cause curving of spinning ball due to generation of pressure difference.

Slice backspin produces an upward Magnus force, slightly counteracting gravity during the ball's ascent, allowing the player to use a lower launch angle while still clearing the net. However, once the spin interacts with drag, the ball rapidly loses forward speed and drops into the court, making slice ideal for short-range precision shots.

Slice superiority

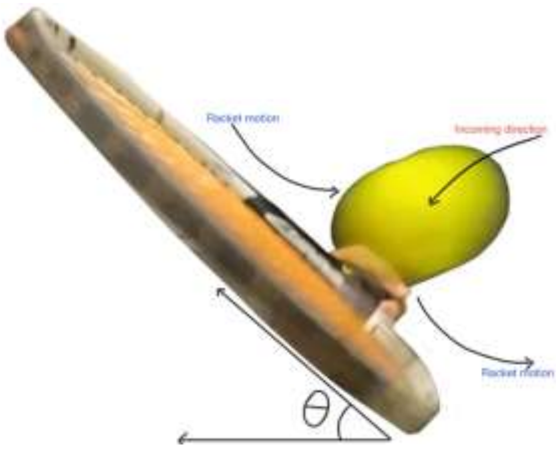
In this study, we assume the use of only slice shots, instead of topspin or flats, due to least potential for bounce and distance coverage- thereby generating an unreturnable shot. Topspin generates significant bounce, and flat shots travel longer, providing an undesirable advantage to the opponent. In slice shots, backspin increases airtime slightly, drag slows down the ball significantly in the horizontal direction, and the bounce height is reduced.





Criteria and variables

Successful slice drop shots need to clear the net (average height of 0.91 m) and land ~0.6-0.9 m past it, covering a total distance of ~12.5 - 13.25 m. A slice-spinning tennis ball experiences an upward Magnus force during ascent and a rapid horizontal deceleration due to drag. This means a drop shot can be hit with a relatively flat angle and still drop quickly after the net.



Data collection

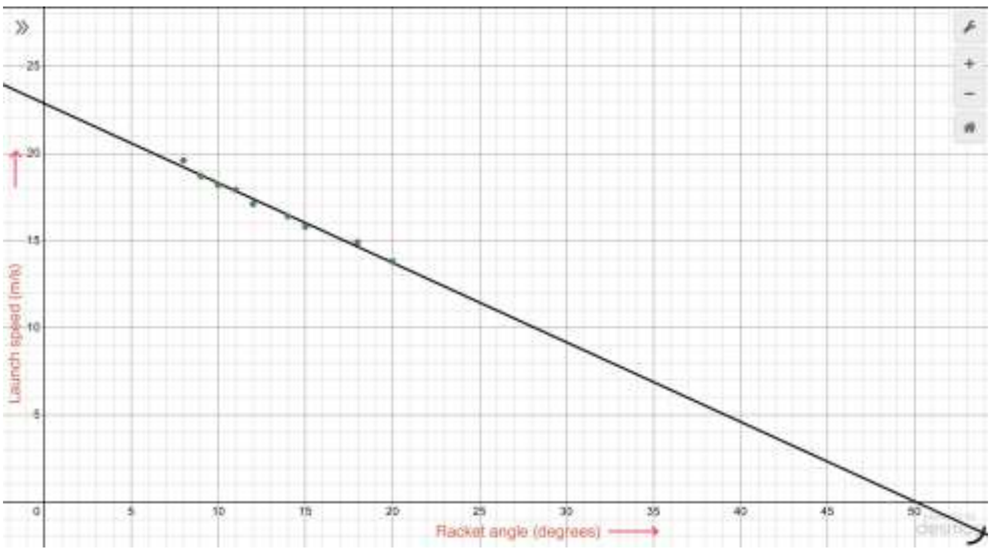
The experiment was conducted on a hard court in low wind conditions. An adult racket and a single brand of professional balls were used. The landing distance was determined using a 15 m measuring tape, and a smartphone on a tripod recording in slow motion was used to determine launch speed and angle using Hudl Technology. The angle was measured with the help of a vertical reference pole in the background, and care was taken to avoid parallax error by placing the phone at exactly waist height / perpendicular to impact.

Trial no.	Racket angle (Degree)	launch Ball Speed (m/s)	Landing distance (m)	Success
1.	8	19.6	13.25	Yes
2.	10	18.2	13.17	Yes
3.	15	15.0	12.30	No
4.	15	15.8	13.25	Yes
5.	12	18.5	13.70	No
6.	17	14.0	12.10	No
7.	12	17.1	13.22	Yes
8.	9	18.7	13.18	Yes
9.	11	17.9	13.10	Yes
10.	14	16.4	12.95	Yes
11.	18	13.5	11.80	No
12.	8	21.0	14.00	No
13.	20	13.8	12.6	Yes
14.	18	14.9	13.21	Yes
15.	10	20.0	13.50	No

Mathematical modelling to derive an empirical expression

In each case, the ball is launched from ~1.5–2.0 m height as a slice, clearing the net (0.91 m high) by only a few tens of centimetres and dropping ~0.7–0.8 m beyond it. The 5–8° flatter shots need much higher speed (~20 m/s) to reach the target, whereas steeper launches (15–18°) work at lower speeds (~15–16 m/s).

For a linear regression, we plot the following graph:



Using intercepts (0, 23) and (50,0) and slope-intercept form → y=mx+c

m= y_2-y_1/x_2-x_1

m=-23/50=-0.46

using (0,23)→ c=23

therefore, $u = 23 - 0.46\theta$

Conclusion

Thus, every 1-degree increase in angle lets us cut ~0.46 m/s off the needed launch speed. Lower angles require significantly higher initial speeds because the ball travels flatter and loses momentum quickly due to drag. Higher angles, however, generate more upward deflection and increased airtime, reducing the need for speed.

While limited by single-racket testing and small timing errors, this study establishes a clear linear relation between racket angle and launch speed for effective slice drop shots. The empirical model reflects how aerodynamic forces - particularly drag and Magnus lift from backspin - shape ball trajectory. These results may assist players and coaches in optimising drop-shot strategy and contribute to future studies involving different spin types and automated measurement tools.

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