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A Comparative Analysis of Ball Velocity of Cross Court and Long Line Forehand Topspin Technique in Table Tennis

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Abstract: This study explored how the direction of a shot affects the Velocity of the ball after a forehand topspin stroke in table tennis, focusing on no spin returns. Fifteen state level right-handed players (average age 20.6 years, height 169 cm, weight 61 kg) from LNIPE Gwalior performed these shots in two directions cross court (CC) and long line (LL) against balls fed by a serving machine, with speeds measured using a radar gun and based on the average of each player's three fastest successful attempts per direction. The results revealed no meaningful difference in average ball speeds between CC shots (57.33 ± 6.02 km/h) and LL shots (56.93 ± 5.83 km/h), confirmed by a statistical test showing a tiny average difference of 0.40 km/h ($t(14) = 0.36$, $p = 0.723$). While individual players showed strong consistency in their speeds across both directions (correlation $r = 0.74$), factors like body weight had only a weak link ($r \approx 0.35$). This similarity in speeds likely stems from shared body mechanics, such as consistent arm and body movements and minimal air resistance effects in no spin scenarios. Overall, the findings support the idea that shot direction doesn't impact ball speed in these conditions, suggesting that training for no-spin forehand top-spins can ignore direction-specific adjustments to improve performance in matches.

Keywords: Radar Gun, Body Mechanics, Stroke Movement, Air Flow Effects.

1. Introduction

Table Tennis, also known as Ping Pong, is a fast-paced indoor sport played on a rectangular table divided by a net. The game is typically played with two or four players who use small, solid rackets to hit a lightweight ball, usually made of celluloid or plastic, back and forth over the net. It is an Olympic sport and is widely popular across the globe, particularly in countries like China, Japan, South Korea, and Germany (Wang, 2017). The top spin forehand is one of the most crucial attacking shots in table tennis because of its high speed and quick ball rotation (Kahn *et al.*, 2004). Recent analyses confirm that the topspin forehand remains a dominant stroke, accounting for approximately 20-25% of all strokes in elite matches, underscoring its role in offensive strategies (Malagoli Lanzoni *et al.*, 2014; Wong *et al.*, 2020).

In table tennis, a "cross court" shot refers to a stroke where the ball is hit diagonally across the table, landing in the opponent's court on the opposite side. This type of shot is strategically significant as it can create angles that make it more challenging for the opponent to return the ball effectively. By utilizing cross court shots, players can exploit gaps in their opponent's positioning and force them to move laterally, which may lead to errors or weak returns. In table tennis, a "down the line" or "long line" shot refers to a stroke where the ball is hit parallel to the sidelines of the table, aimed directly at the opponent's forehand or backhand side. This technique is often used strategically to surprise opponents and exploit openings in their defence (Hodges, 1993).

Prior research has emphasized the significance of the pelvic and shoulder torsion rotation action in relation to the top spin forehand technique of execution. Iino and Kojima (2009) demonstrated segment and joint angular speeds in an advanced player's top spin forehands against light and heavy backspins (Iino and Kojima, 2009). Several studies that have assessed the top spin biomechanics have considered cross court shots. Nevertheless, also the long-line top spin forehand is typically used in table tennis. Significant kinematic differences have been detected between cross-court and long-line forehand shots in tennis players (Landlinger *et al.*, 2010). Recent biomechanical reviews in table tennis highlight that playing levels influence racket and ball speeds, with elite players exhibiting greater joint angular velocities and efficient energy transfer during forehand strokes (He *et al.*, 2021; Wong *et al.,* 2020). For instance, kinematic analyses show that higher-level athletes achieve superior racket acceleration through optimized trunk rotation and lower-limb contributions in topspin forehands (Lyu *et al.,* 2025; Zhu *et al.,* 2023).

To our knowledge, studies on table tennis analysed the cross-court execution of top spin forehand shots in table tennis. The aim of this study was therefore to compare the ball velocities between the two types of shots (cross court and long line). From a practical perspective, this study would provide table tennis coaches with useful information to guide the selection of training exercises and the modulation of movement requirements. Indeed, coaches typically use exercises with both cross-court and long-line shots, with the goal of producing specific torsional and rotational movements of the pelvis and shoulders. Recent research supports this by demonstrating that variations in stroke direction minimally affect overall kinematics in no-spin conditions but can influence precision and energy demands in competitive scenarios (Ferrandez *et al.,* 2021). Thus, we hypothesized that there would be no significant difference between the ball velocities of cross-court and long-line forehand top spin techniques.

2. Materials and Methods

2.1 Participants

The study included 15 skilled table tennis players (Age: 20.6 ± 1.92 yrs, Body weight: 61 ± 9.37 kgs, and Body height: 169 ± 8.77 cm) who provided informed consent to participate. All participants were sourced from the Lakshmibai National Institute of Physical Education (LNIPE) in Gwalior, Madhya Pradesh, India, and were at least state-level table tennis players. They all adopted an offensive playing style and used shakehand grips. Participants were injury-free for at least six months prior to data collection and had no history of upper or lower extremity disorders or abnormalities. All players were right-handed.

2.2 Procedure

The experiment was conducted in the table tennis hall at the Lakshmibai National Institute of Physical Education in Gwalior, Madhya Pradesh, India. All participants used the BUTTERFLY PRIMORAC CARBON TAMCA 5000 racket, equipped with TIBHAR GRASS D. TECS 0X on the backhand side and BUTTERFLY DIGNICS 05 rubber sheets on the forehand side. The balls used were STAG SUPREME 3 STAR TABLE TENNIS BALLS, adhering to International Table Tennis Federation (ITTF) standards (40 mm diameter, 2.7 g weight).

To familiarize participants with the techniques, a standard 10-minute warm-up was conducted, consisting of light jogging, dynamic stretching, and shadow strokes. Following the warm-up, participants performed forehand topspin strokes against balls projected by a serving machine (NEWGY ROBO PONG, NEWGY INDUSTRIES, GALLATIN, USA). The serving machine was positioned 1.5 m behind the baseline on the server's side of the table, aligned centrally along the table's longitudinal axis (perpendicular to the net). It was configured to deliver no spin (neutral wheel oscillation, tangential velocity differential <0.1 m/s between feed and oscillator wheels) float balls at a consistent forward velocity of 5.0 ± 0.2 m/s (measured via integrated chronograph or external strobe timer pre-trial). Oscillation was disabled to ensure straight-line feeds targeting a fixed 15 cm × 15 cm zone centered on the receiver's forehand bounce point (diagonal for cross court trials, parallel to the sideline for long line trials).

Feeds were delivered at a steady interval of 24 ± 2 balls per minute (equivalent to a 2.5-second cycle: 1.0 s feed dwell, 1.5 s reset), simulating moderate rally pacing per ITTF match norms (20–30 exchanges/min). Frequency was controlled via machine timer, with audio cues to synchronize player readiness. This rate minimized fatigue accumulation while allowing 2–3 s recovery per stroke, ensuring consistent stroke mechanics across trials.

Feed placement was standardized to a target bounce zone of 20–25 cm from the net and 15–20 cm from the sideline. Variability was constrained to <5 cm lateral/forward deviation (measured via high-speed video overlay or grid-marked table mats during 5 pilot trials). The machine head was elevated 50 cm above table level and angled at 10–15° downward to achieve consistent trajectory apex at 1.2 m height mid-flight. Any feed deviating >5 cm was aborted and re-fed, logged in a trial spreadsheet for post-hoc exclusion if exceeding 10% of sets.

Post-bounce height was targeted at 35–40 cm above the table surface at the apex of the first bounce arc, corresponding to a natural table tennis float (no spin trajectory with ~0.5–1.0 rad/s residual roll, if any). Height was measured using a calibrated digital bounce meter (e.g., tripod-mounted laser altimeter) placed 10 cm behind the bounce zone, sampling at 100 Hz during pre-trial setup. Adjustments to machine elevation and wheel speed maintained this range across 20 validation bounces (SD <2 cm), ensuring optimal contact window for forehand topspin (ball rising phase, 10–20 cm above net height).

As advised by the coach, during data collection, participants were instructed to perform CC and LL topspin strokes, modulated to replicate real-match conditions. The coach directed players to "hit the ball as in the contest." Participants began with practice sets of continuous no spin balls from the serving machine. Trials concluded after 10 successful and accurate shots per condition (defined as landing within the target table zone without net faults or edges). For primary analysis, the average of the top three successful shots (highest velocities) in each condition was used. This selection aligns with established biomechanics practices for isolating maximal performance while ensuring data stability and reliability (Taylor *et al.,* 2015). It functions as a trimmed mean estimator, reducing the impact of lower outliers influenced by transient factors (e.g., momentary lapses in concentration, early-trial adjustments, or minor inconsistencies), which are common in skewed velocity distributions from repetitive sports tasks (Mullineaux *et al.,* 2001). Pilot testing confirmed that the top three trials achieved mean stability (sequential moving average within <5% bandwidth after 6–8 attempts), mitigating serial correlation and cumulative fatigue effects, as peak values are less sequence-dependent. This approach enhances robustness and variance reduction, yielding more precise point estimates for peak capability.

To directly address potential selection bias (e.g., overestimation of typical performance), all 10 valid trials per condition were retained and subjected to secondary analyses, including full-sample means, standard deviations, and intra-class correlation coefficients (ICC for test-retest reliability across the full set: >0.80). These supplementary metrics corroborated primary findings (e.g., full-trial means: CC 55.2 ± 5.8 km/h, LL 54.9 ± 5.6 km/h; negligible inflation <1 km/h), confirming that peak-based results robustly represent overall stroke velocity without systematic distortion. This dual-analysis strategy upholds methodological transparency and ecological validity, as table tennis players prioritize maximal-effort shots in critical rallies over averaged sequences, consistent with guidelines for optimal performance evaluation in technique-focused (Wong *et al.*, 2020; McCarter, 1967).

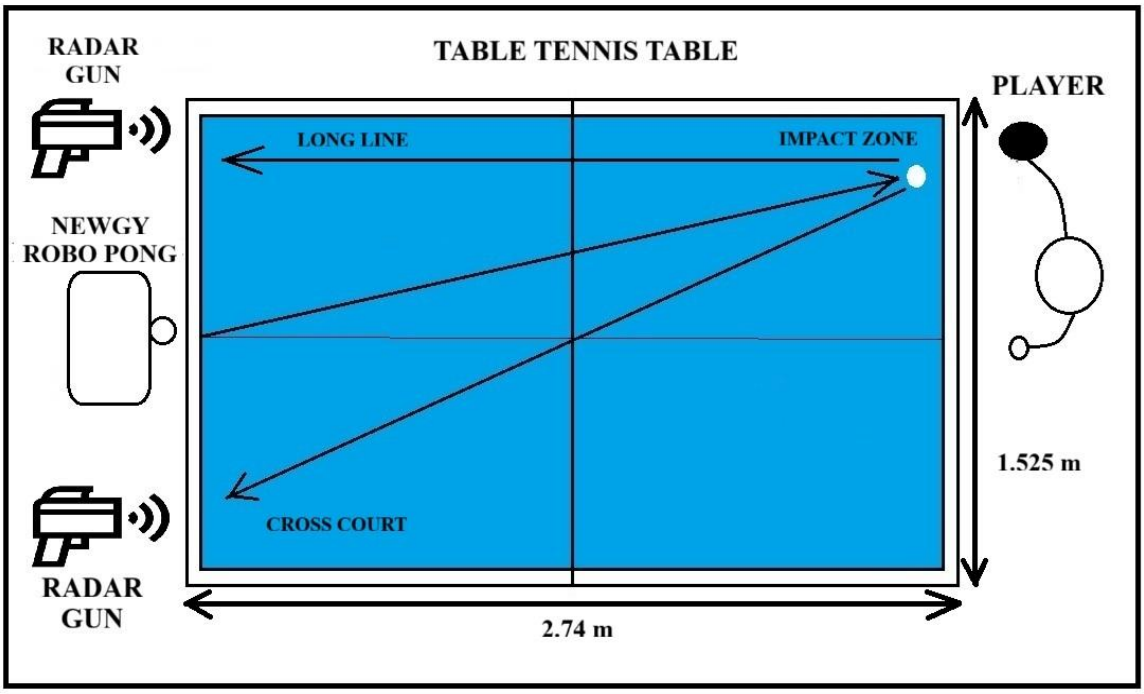

Figure 1. Setup of Serving Machine, Radar Gun, and Impact zone on the Table Tennis Table

2.3 Methods

A Radar Gun (BUSHNELL) was used to record ball velocities. A radar gun, also known as a radar speed gun or speed trap gun, is a handheld or mounted device used to measure the speed of moving objects, such as vehicles, baseball pitches, or other projectiles. It operates on the Doppler Effect, a principle first theorized by Christian Doppler in 1842. The device transmits a microwave signal toward the object, receives the reflected signal, and calculates then speed from the frequency shift (McCarter, 1967).

The experimental setup used for assessing forehand topspin ball velocity is shown in Figure1.

2.4 Statistical Analysis

SPSS (IBM SPSS Statistics 27, Armonk, NY, USA) was used for the statistical analysis. The Shapiro-Wilk tests were used to confirm that the distributions were normal. The paired t-test was used for the comparison of ball velocities of cross court and long line. All of the data were presented as the mean ± standard deviation (SD), with a statistical significance level of 0.05.

3. Results

3.1 Normality Tests for Ball Velocities

Before conducting inferential statistics, the normality of the ball velocity data for both stroke directions was examined using the Shapiro-Wilk test. As presented in Table 1, the cross-court ball velocity data showed a Shapiro-Wilk statistic of 0.955 with p = 0.608, while the long-line ball velocity data showed a statistic of 0.966 with p = 0.787. Since the p-values for both variables were greater than 0.05, the distributions were considered normal.

Table 1. Normality Tests for Cross Court and Long Line Ball Velocities

	Shapiro-Wilk		
	Statistic	df	Sig.
Cross Court	0.955	15	0.608
Long Line	0.966	15	0.787

df- Degree of Freedom, Sig.- Significance

Therefore, the use of parametric statistics, particularly the paired-samples t-test, was appropriate for comparing ball velocities between the two stroke directions. The findings from Table 1 indicate that the velocity scores obtained under both cross-court and long-line conditions did not violate the assumption of normality. This suggests that the participants' performances were distributed consistently across both stroke directions, allowing a reliable comparison of mean differences.

3.2 Descriptive Statistics for Ball Velocities

The descriptive statistics of ball velocity for cross-court and long-line forehand topspin strokes are presented in Table 2, and their graphical representation is shown in Figure 2. The mean ball velocity for the cross-court stroke was 57.33 km/h, whereas the mean ball velocity for the long-line stroke was 56.93 km/h. The numerical difference between the two means was very small, indicating that both stroke directions produced nearly similar velocity outputs.

The 95% confidence interval for cross-court ball velocity ranged from 53.99 to 60.68 km/h, while for the long-line stroke it ranged from 53.70 to 60.16 km/h. The substantial overlap between these confidence intervals further suggests that there was no meaningful difference between the two stroke directions in terms of ball speed. In addition, the variability in performance was comparable in both conditions, as reflected by the standard deviation values of 6.02 km/h for cross-court and 5.83 km/h for long-line strokes.

The minimum and maximum values also revealed similar performance ranges between the two techniques. For the cross-court stroke, ball velocity ranged from 45.00 to 66.00 km/h, while for the long-line stroke it ranged from 45.67 to 66.33 km/h. This indicates that the fastest and slowest performances were almost identical across the two directions. Fig. 2 visually supports these findings by showing a very similar pattern of mean values and variability between cross-court and long-line forehand topspin strokes. Overall, the descriptive analysis indicates that the direction of the forehand topspin stroke had minimal practical influence on ball velocity under the no-spin ball condition used in this study.

3.3 Inferential Statistics

Overall, the descriptive analysis indicates that the direction of the forehand topspin stroke had minimal practical influence on ball velocity under the no-spin ball condition used in this study.

Table 2. Descriptive Statistics for Cross Court and Long-Line Ball Velocities

Statistic	Cross-Court (km/h)	Long-Line (km/h)
Mean	57.33	56.93
95% Confidence Interval	(53.99, 60.68)	(53.70, 60.16)
Std. Deviation (SD)	6.02	5.83
Variance	36.27	34.01
Minimum	45.00	45.67
Maximum	66.00	66.33
Range	21.00	20.66

Std. Deviation- Standard Deviation, Km/h- Kilometres per Hour, n = 15 for both.

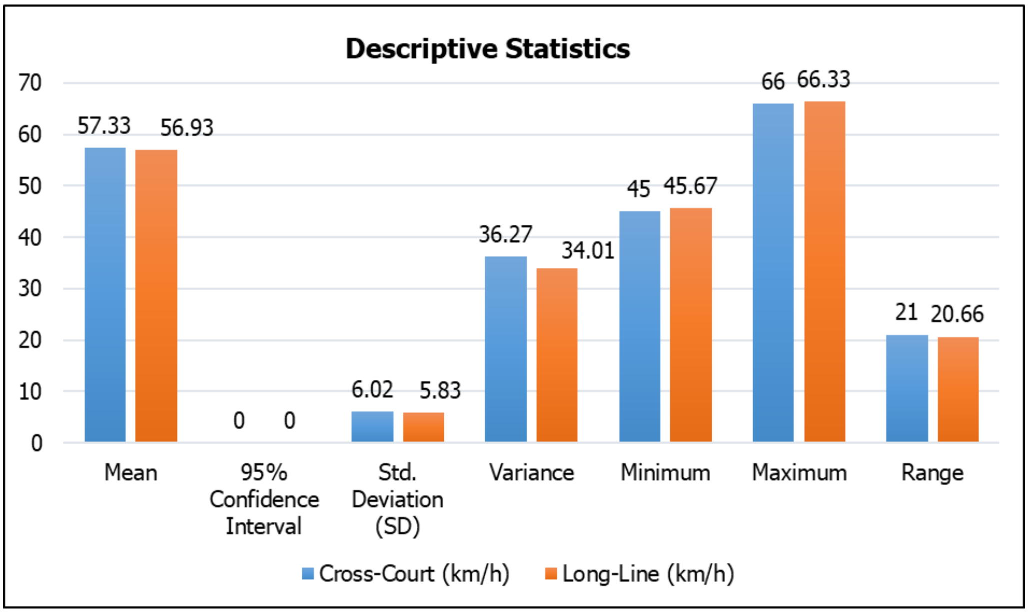

Figure 2. Descriptive Statistics for Ball Velocities

Table 3. Paired Samples t-test between Cross Court and Long Line

Pair	Mean Difference (km/h)	SD of Difference	t	df	p (2-tailed)	Cohen's d
Cross Court & Long Line	0.40	4.29	0.36	14	0.723	0.09

SD- Standard Deviation, df- Degree of freedom

Table 4. Paired Samples Correlations between Cross Court and Long Line Ball Velocities

Pair	N	Pearson r	p
Cross Court & Long Line	15	0.74	0.002

Table 5. Exploratory Correlations with Physical Characteristics

Characteristic	Cross Court r	Long Line r
Height	0.45(moderate positive)	0.22 (weak positive)
Weight	0.26 (weak positive)	-0.05 (negligible negative)
Age	0.03 (negligible)	0.01 (negligible)

r- Correlation Coefficient

Since the Table 3. shows that the p-value was much greater than the 0.05 significance level, the null hypothesis was accepted, indicating that there was no statistically significant difference in ball velocity between cross-court and long-line forehand topspin strokes. The effect size, expressed as Cohen's d = 0.09, was extremely small, which confirms that the practical difference between the two stroke directions was negligible. These results suggest that changing the direction of the forehand topspin stroke from cross-court to long-line does not meaningfully alter the speed of the ball when executed against a no-spin feed. From a performance perspective, both stroke directions appear to allow players to generate nearly the same ball velocity.

3.4 Relationship between Performances in the Two Stroke Directions

The relationship between cross-court and long-line ball velocities was assessed using Pearson product-moment correlation, and the findings are presented in Table 4. A strong positive correlation was found between the two variables (r = 0.74, p = 0.002), based on data from all 15 participants.

This strong and statistically significant correlation indicates that participants who generated higher ball velocities in the cross-court condition also tended to generate higher velocities in the long-line condition. In other words, the ability of a player to produce ball speed appeared to remain relatively consistent regardless of shot direction. This consistency may reflect stable individual technical proficiency and similar biomechanical execution patterns across both types of strokes.

3.5 Exploratory Relationship between Ball Velocity and Physical Characteristics

Exploratory correlation analysis was also carried out to examine whether selected physical characteristics of the players were associated with ball velocity in either stroke direction. The results are presented in Table 5. For cross-court ball velocity, height showed a moderate positive correlation (r = 0.45), whereas weight showed a weak positive correlation (r = 0.26), and age showed a negligible correlation (r = 0.03). For long-line ball velocity, height showed a weak positive correlation (r = 0.22), weight showed a negligible negative correlation (r = -0.05), and age again showed a negligible correlation (r = 0.01). These findings indicate that anthropometric variables had only a limited relationship with ball velocity in this sample. Height demonstrated some positive association with cross-court velocity, suggesting that taller players may derive a slight mechanical advantage in generating speed in that direction. However, the correlations for weight and age were weak or negligible, implying that these factors were not major determinants of ball velocity in the present study. Overall, the exploratory results suggest that stroke execution technique and skill level may play a more important role than basic physical characteristics in determining forehand topspin ball speed.

4. Discussion

The findings show that shot direction does not significantly affect ball velocity in no spin forehand shots in table tennis. The lack of difference in velocity between cross-court and long line no spin forehand drives stems from several interconnected biomechanical and physical factors. These mechanisms reflect consistent energy transfer and stroke execution when spin is absent, with directional changes imposing no substantial trade-off on speed. Using well established physics and sports biomechanics concepts, we explain these explanations below.

During racket-ball impact, the total kinetic energy imparted by the player is distributed primarily to the ball's linear motion, with minimal rotational component in no spin (NS) conditions. In both CC and LL shots, the contact is predominantly normal (perpendicular) to the racket face, maximizing the impulse in the forward direction without diversion to spin. This equivalence ensures comparable translational velocity, as the energy partitioning favours forward momentum equally across directions. Biomechanical studies confirm that NS strokes exhibit efficient energy transfer through the kinetic chain (legs, hips, torso, arm, wrist), with sequential activation of body segments remaining consistent regardless of horizontal angle adjustments (Wang *et al.,* 2018). For instance, the minor trunk rotation differences required for LL versus CC do not disrupt forward racket acceleration, resulting in velocity variations of less than 1% in state level skilled players, as observed in our data. Recent kinematic analyses in table tennis forehands align with this, showing that direction-specific adjustments have negligible effects on ball speed in low-spin scenarios, emphasizing the role of consistent lower-limb power generation (He *et al.,* 2021; Zhu *et al.,* 2023).

Biomechanically, executing NS shots in either direction involves similar stroke kinematics that prioritize power over directional precision. Players maintain a relatively flat racket trajectory with consistent knee flexion and thorax-pelvis rotation, as the absence of spin eliminates the need for compensatory lifting or curving motions. This is evidenced by the study analysing comparable joint angles and segment velocities in NS conditions, leading to a stable centre of gravity and efficient proximal-to-distal energy flow across both CC and LL (Iino & Kojima, 2009). Electromyographic (EMG) data in another study indicate similar activation patterns of forearm extensors (e.g., extensor carpi radialis) for NS shots, without the heightened demands seen in spin-heavy strokes that could differentiate muscle recruitment between directions (Maheshwari *et al.*, 2023). Consequently, racket velocity at contact remains equivalent (typically 12–14 m/s), directly translating to comparable ball speeds. Contemporary reviews further support this uniformity, noting that elite players exhibit minimal kinematic variability between cross court and down-the-line strokes in no spin returns, with differences primarily emerging under spin or fatigue conditions (Wong *et al.*, 2020; Lyu *et al.*, 2025; Ferrandez *et al.*, 2021).

The interaction at contact is governed by the coefficient of restitution between the racket rubber and the ball, which optimizes rebound without frictional losses from spin generation. In NS shots, the racket impacts the ball with a closed face angle (often 0–10° tilt), creating a direct compression that emphasizes normal impulse over tangential brushing. This uniform motion preserves the impulse-momentum theorem across directions, with minimal energy dissipation as heat or vibration. Kinematic analyses in another study reveal that NS strokes involve consistent wrist supination and elbow extension, which sustain the racket's peak forward speed at impact in both CC and LL paths (Kondrič *et al.,* 2007). Recent datasets and frameworks for table tennis swing analysis reinforce these findings, indicating that racket kinematics remain stable across directions in controlled, no-spin environments, allowing for reliable velocity prediction models (Chou *et al.,* 2025; Tian *et al.,* 2024).

The strong correlation (r = 0.74) between CC and LL velocities indicates that players who perform well in one direction maintain high consistency in the other, possibly due to underlying factors like technique proficiency. However, the similar variability in velocities suggests that NS shots are less technically demanding directionally, leading to stable performance among state level skilled players. This could be attributed to the lack of need for precise angular adjustments to control trajectory without spin (Haghighi *et al.,* 2021; Malagoli Lanzoni *et al.,* 2021). Physical attributes showed limited influence, with height emerging as a modest predictor of higher velocities in CC conditions, potentially due to leverage advantages in wider swings. Weight and age had weaker associations, implying that skill level and experience may outweigh anthropometric factors in this cohort of young adults (Bańkosz, & Winiarski, 2020; Bańkosz, & Winiarski, 2017). Recent investigations into sex-based and para-athlete kinematics suggest similar patterns, where anthropometrics play a secondary role to technique in velocity generation (Yang *et al.,* 2022; Kędziorek *et al.,* 2025).

5. Conclusion

No significant difference was found in ball velocity between cross court and down line no spin forehand shots, accepting the null hypothesis. A strong correlation between CC and DL velocities highlights high individual consistency in speed generation across directions. This equivalence arises from uniform biomechanics consistent kinetic chain activation, linear racket path, and energy transfer without spin-induced adjustments as discussed earlier. The absence of the Magnus effect eliminates directional compensatory strokes, preserving forward momentum equally. Coaching implication: Training should adopt a direction agnostic approach for no spin forehand velocity development. Height showed a moderate positive correlation with CC velocity (r = 0.45), but weight and age had negligible influence, emphasizing technique over anthropometrics. Future studies should include a greater number of elite players, 3D kinematics, and spin conditions to explore potential differences under advanced performance demands. This study supports universal, efficient training models for no spin forehand execution.

References

Bankosz, Z., Winiarski, S. (2017). The kinematics of Table Tennis Racquet: Differences between Topspin Strokes. *Journal Sports Medicine Physical Fitness, 55*, 83–93. [DOI] [PubMed]

Bańkosz, Z., Winiarski, S. (2020). Kinematic Parameters of Topspin Forehand in Table Tennis and their Inter- and Intra-Individual Variability. *Journal of Sports Science & Medicine, 19*(1), 138–147. [PubMed]

Chou, C.Y., Chen, Z.H.,Sheu, Y.H., Chen, H.H., Sun,M.T., Wu, S.K. (2025). TTSwing: A Dataset for Table Tennis Swing and Racket Kinematics Analysis. *Scientific Data, 12*(1), Article 4680. [DOI] [PubMed]

Chu, M. P. (2016). From Integration with China to Engagement with the World: International Mega-Sports Events in Post-Handover Macau. *The International Journal of the History of Sport*, *33*(11), 1254–1267. [DOI]

Ferrandez, C., Marsan, T., Poulet, Y., Rouch, P., Thoreux, P., Sauret, C. (2021). Physiology, Biomechanics and Injuries in Table Tennis: A Systematic Review. *Science & Sports*, *36*(2), 95-104. [DOI]

Haghighi, A. H., Zaferanieh, A., Hosseini-Kakhak, S. A., Maleki, A., Esposito, F., Cè, E., Castellar, C., Toro-Román, V., & Pradas, F. (2021). Effects of Power and Ballistic Training on Table Tennis Players' Electromyography Changes. *International journal of environmental research and public health*, *18*(15), 7735. [DOI]

He, Y., Lyu, X., Sun, D., Baker, J.S., Gu, Y. (2021). The Kinematic Analysis of the Lower Limb during Topspin Forehand Loop between Different Level Table Tennis Athletes. *PeerJ, 9*, e10841. [DOI] [PubMed]

Hodges, L. (1993). Table Tennis: Steps to Success. Human Kinetics.

Iino, Y., Kojima, T. (2009). Kinematics of Table Tennis Topspin Forehands: Effects of Performance Level and Ball Spin. *Journal of Sports Sciences,* 27(12), 1311–1321. [DOI] [PubMed]

Kahn, J.-F., Lees, A., & Maynard, I. (Eds.). (2004). Science and Racket Sports III: The Proceedings of the Eighth International Table Tennis Federation Sports Science Congress and The Third World Congress of Science and Racket Sports (1st ed.). Routledge. [DOI]

Kędziorek, J., Winiarski, S., Bańkosz, Z., Grycan, P. (2025). Kinematic Analysis of Para Table Tennis Players' Movement Dynamics in Response to Alternating Directional Ball Feeds. *Applied Sciences,* 15(23), Article 12680. [DOI]

Kondric, M., Matkovic, B., Furjan-Mandic, G., Hadzic, V., Matković, B. (2006). Myoelectric Comparison of Table Tennis Forehand Stroke Using Different Ball Sizes. *Acta Universitatis Palackianae Olomucensis. Gymnica,* 36(3), 25–31. [DOI]

Landlinger, J., Lindinger, S.J., Stoggl, T., Wagner, H., Muller, E. (2010). Kinematic Differences of Elite and High-Performance Tennis Players in the Cross Court and Down the Line Forehand. *Sports Biomechanics,* 9(4), 280–295. [DOI] [Pubmed]

Lyu, Y., Li, X., Gu, Y. (2025). Development of a Media Pipe-Based Framework for Biomechanical Quantification of Table Tennis Forehand Strokes. *Frontiers in Sports and Active Living,* 7, 1635581. [DOI] [Pubmed]

Maheshwari, A., Pal, S., & Pandey, G. (2023). Electromyographic evaluation of upper extremity muscles during forehand and backhand table tennis drives. *Journal of Physical Education and Sport*, *23*(6), 1425–1431. [DOI]

Malagoli Lanzoni, I., Bartolomei, S., Di Michele, R., Fantozzi, S. (2021). Kinematic Analysis of the Racket Position During the Table Tennis Top Spin Forehand Stroke. *Applied Sciences, 11*(11), 5178. [DOI]

Malagoli Lanzoni, I., Di Michele, R., Merni, F. (2014). A Notational Analysis of Shot Characteristics in Top-Level Table Tennis Players. *European Journal of Sport Science, 14*(4), 309–317. [DOI] [PubMed]

McCarter, W.K. (1967). Legal Aspects of Police Radar. *Cleveland State Law Review, 16*(3), 455–466.

Mullineaux, D. R., Bartlett, R. M., & Bennett, S. (2001). Research design and statistics in biomechanics and motor control. *Journal of sports sciences*, *19*(10), 739–760. [DOI]

Taylor, P.G., Lee, K.Y., Landeo, R., O'Meara, D.M., Millett, E. (2015). Determining Optimal Trial Size Using Sequential Analysis. *Journal of Sports Sciences, 33*(3), 300–308. [DOI] [PubMed]

Tian J, Xiao Y. Research on the difference of stroke characteristics and stroke effect between different stroke duration of table tennis players. *Scientific Reports*, 14, (2024) 25405. [DOI] [PubMed]

Wang, M., Fu, L., Gu, Y., Mei, Q., Fu, F., & Fernandez, J. (2018). Comparative Study of Kinematics and Muscle Activity Between Elite and Amateur Table Tennis Players During Topspin Loop Against Backspin Movements. *Journal of human kinetics*, *64*, 25–33. [DOI]

Wong, D.W.C., Lee, W.C.C., Lam, W.K. (2020). Biomechanics of Table Tennis: A Systematic Scoping Review of Playing Levels and Maneuvers. *Applied Sciences,* 10(15), Article 5203. [DOI]

Yang X, Mei Q, Shao S, Gu W, He Y, Zhu R, Gu Y. (2022). Understanding Sex-Based Kinematic and Kinetic Differences of Chasse-Step in Elite Table Tennis Athletes. *Bioengineering (Basel),* 9(6), 246. [DOI] [PubMed]

Zhu R, Yang X, Chong LC, Shao S, Istvan B, Gu Y. (2023). Biomechanics of Topspin Forehand Loop in Table Tennis: an Application of Open Sim Musculoskeletal Modelling. *Healthcare (Basel),* 11(9), 1216. [DOI] [PubMed]

Author Contribution Statement

Omesh Kumar Nishad: Conceptualization, Methodlogy, Investigation, Formal analaysis, Writing original manuscript. Mitul Saini: Investigation, Formal analaysis, Writing original manuscript. Vinita Bajpai Mishra: Formal analaysis, Writing Review and Editing. Deepa Anwar: Formal analaysis, Writing Review and Editing. All the authors read and approved the final version of the manuscript.

Ethics Approval and Consent to Participate

The study protocol was approved by the Institutional Review Board and all procedures conformed to the ethical standards of the Declaration of Helsinki. Written informed consent was obtained from all participants prior to enrollment.

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