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Original Article

Influence of kinematic and anthropometric factors on drag–flick performance in field hockey

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Abstract
Problem Statement: The drag–flick performance can be improved by understanding the effect of kinematic and anthropometric factors on the ball velocity of the drag–flick shot in field hockey. **Purpose:** The purpose of this study was to identify the association and influence of the selected kinematic and anthropometric factors on the ball velocity of the drag–flick in field hockey. **Methods:** The kinematic factors of 64 drag–flicks of 16 (female = 8, male = 8) national elite hockey players were measured through 3D biomechanical analysis using VICON motion capturing system and MATLAB software. Pearson correlation and regression analysis were used for statistical analysis. **Results:** The ball velocity had significant correlation with drag length ($r = 0.70$, $p < 0.01$), drag time ($r = 0.29$, $p < 0.05$), drag velocity ($r = 0.59$, $p < 0.01$), stance width ($r = 0.53$, $p < 0.01$), average right knee angle ($r = -0.36$, $p < 0.01$), average left elbow angle ($r = -0.31$, $p < 0.05$), age ($r = -0.32$, $p < 0.05$), weight ($r = 0.36$, $p < 0.01$), and height ($r = 0.39$, $p < 0.01$). Drag length ($\beta_1 = 4.63$), stance width ($\beta_2 = 8.19$), average right knee angle ($\beta_3 = -0.07$), age ($\beta_4 = -1.62$), and height ($\beta_5 = 0.15$) had significant ($p < 0.05$) influence on the ball velocity of the drag–flick. **Conclusion:** To make a drag–flick with high ball velocity, the players maximize their ball drag length and stance width while minimizing their average right knee angle. In addition, the players' height had a significant and positive contribution towards the ball velocity. The coaches should focus on the drag length and stance width of the flickers to increase their performance.
Keywords: Kinematics, Ball Velocity, Players, Drag Flick, Hockey

Introduction

In field hockey, the penalty corner is a significant part, which is considered as a brilliant chance to make a goal for the win. This segment includes three specialized applications (i.e., push in, stop, and drag–flick) in which drag–flick has a significant relationship with goal-scoring (Ledru et al., 2019). The drag–flick technique is known as the highest goal-scoring technique in field hockey, and the dynamics of each phase of this technique is important in terms of performance (Bari et al., 2014). This technique can be described as a synchronization of muscle actions and body motion targeting to attain high velocity of the stick head (Ibrahim, 2016), which results in high ball velocity and less time for goal keeper to save the goal. A drag–flick contains four major phases, i.e., the approach, contact, dragging, and follow through (Eskiyecek, 2018). It is usually recognized that the collaboration of body parts in each segment transfers energy towards stick head and finally results in high ball velocity (Ibrahim et al., 2016).

This segment requires physical fitness and the use of biomechanical skills (Sharma et al., 2012). The ball speed of the drag–flick has a strong association with the kinematic factors applied on the stick and ball (Eskiyecek et al. 2018).

Baker et al. (2009) measured the ball velocity using a radar gun and found that the average ball velocity of the players in drag–flick performance was 30.5 m/s; Husain et al. (2012) discovered that the ball velocity during the drag–flick was 30.99 ± 4.33 m/s among college players, and the ball velocity was 31.85 ± 0.86 m/s for the players playing at national level.

A few studies have been conducted on biomechanical analysis of the drag–flick in field hockey (Ratko et al., 2006; Baker et al., 2009; Lopez-de-Subijana et al., 2010; Gomez et al., 2012; Verma 2014; Bari et al., 2014; Palaniappan and Sundar, 2016; Gurol and Yilmaz, 2006; Ibrahim et al., 2016; Eskiyecek et al., 2018; Ladru et al., 2019). In these previous studies, the kinematic data of the drag–flicks of the players at national and international levels (Lopez-de-Subijana et al., 2010) were obtained. Therefore, biomechanical analysis is critical for identifying the key mechanical features of the physical performance of the drag–flickers (Gomez et al., 2012). Similarly, the players' attributes (e.g., height, weight, and age) and their physiological performance are associated with drag–flick performance (Verma, 2014).

It was identified (Palaniappan and Sundar, 2016) that several kinematic factors affected the ball velocity of the drag–flick shots. It has been also reported that high ball velocity can be attained with the optimum ball

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approach distance, high stick speed, and large ball dragging length (Ibrahim et al., 2016). It has been concluded that the elbow (angle) movement and knee extension are important for an accurate drag–flick shot (Ratko et al., 2006); it has been also established that the extension of the elbow significantly increased the ball velocity of the drag–flick (Gurol and Yılmaz, 2016).

In previous studies, two-dimensional (2D) and three-dimensional (3D) biomechanical analyses of the drag–flick performance were performed, and the kinematic data were obtained using X-sense Technologies and VICON motion capturing system (Ladro et al., 2019; Eskiyecek et al., 2017; Ibrahim et al., 2016). Different factors (e.g., ball velocity, approach time at the ball, knee and elbow angles, and ball dragging distance) were analyzed with high-speed cameras and computer software in several countries (Eskiyecek et al., 2018). The body movements of the flickers was evaluated to improve their performance in competitions and the criterion for assessing the performance with high ball velocity. It was determined that higher knee extension velocity contributed to higher ball velocity in elite players (Ladru et al., 2019).

Research on the influence of kinematic factors and anthropometric attributes on the ball velocity in drag–flick performance is less prevalent in hockey but the relationship of body actions with ball velocity in baseball and football has been previously established (Graaff et al., 2018). Therefore, there is a need to investigate the influence of biomechanical and anthropometric factors on the performance of the drag–flick in field hockey in national elite players.

Consideration of the kinematics of a drag–flick performance and anthropometric attributes of the players may be helpful for improving the performance of the drag–flickers (Augustus et al., 2007). If the influence of dragging length, dragging velocity, stance width, knee and elbow angles, height and weight on ball velocity of the drag–flick performance is established then this scientific model can used for improving the drag–flick performance of the national elite players. Therefore, the aim of this study was to determine whether the selected kinematic and anthropometric factors had a significant effect on the ball velocity. It was hypothesized that selected biomechanical and anthropometric factors had a significant influence on the ball velocity of the drag–flick in field hockey.

Materials and Methods

Participants

This study was performed on eight male and eight female national elite players. The players were 15–21 years old. They had at least one year of playing experience at national or international level, and they participated voluntarily. None of the participants underwent any professional training regarding the drag–flick. All of the them were informed about the study, their consent was obtained, and none of them had any medical fitness issues. Each player performed 4–5 drag flick; therefore, the data of 64 drag–flicks were analyzed. This research was approved by the Departmental Research Committee (DRC) and the Board of Studies, The University of Lahore, Pakistan.

Measures

Based on the previous studies, Qualisys Track Manager Software was used to capture the drag–flick performance (Eskiyecek et al., 2018). An active marker motion analysis system was used after calibration with 16 markers. Eight cluster markers were attached to different body segments (the thighs were modeled between the shanks and pelvis) to obtain a full-body model (Ibrahim et al., 2016). The 3D data of thirty-one elite players were obtained using the Max TRAQ 3D motion analysis software (Ansari et al., 2014). The kinematic data were recorded using a motion capture suit (X-sense Technologies B.V., Enschede, Netherlands) at 240 Hz (Ladru et al., 2019). This system was validated against a VICON Motion Analysis System for the lower extremity and pelvis kinematics during high-velocity movements in sport-specific settings (Blair et al., 2018).

Based on the previous studies, the researcher adapted 3D videography kinematic methodology to obtain the kinematic factors of the drag–flick using the VIVON motion capturing system in the Biomechanics Laboratory at Lahore University of Management Sciences (LUMS), Lahore, Pakistan. All players used their standardized sticks with proper kits and performed drag–flicks after a proper warm-up. A single standardized field hockey ball, weighing 156–163 g with a diameter of 12.5 cm and an attached reflector was used. Fourteen markers (see Figure 1a) were placed on the players' body, and two markers were placed on the hockey stick.
The measurements of the drag–flicks were recorded with a VICON (Nexus 2.8.2) motion capturing system with sixteen cameras. Fourteen infrared (IR) cameras (Basler Pi A640-210GC) with a 250 Hz frame rate and two high-speed video cameras (YCON MxF20) with a 125 Hz frame rate were used. MATLAB software was used for data capturing, labeling, and filtering. All drag–flicks were performed in stationary ball position without a goalkeeper.

In this study, kinematic measurements were recorded from the starting phase to the follow-through phase. The approach distance was measured manually; drag length, drag time, drag velocity, stance width, and the ball velocity were computed from VICON motion capturing system and MATLAB software. The average knee and elbow angles were also computed from VICON system obtained from the start to the end of dragging (Figures 2&3) based on camera frames. The height and weight of the players were measured manually using available standardized equipment; age was recorded as described in the participants' registration documents. The ball velocity was considered as a dependent variable, while other variables were treated as independent variables.

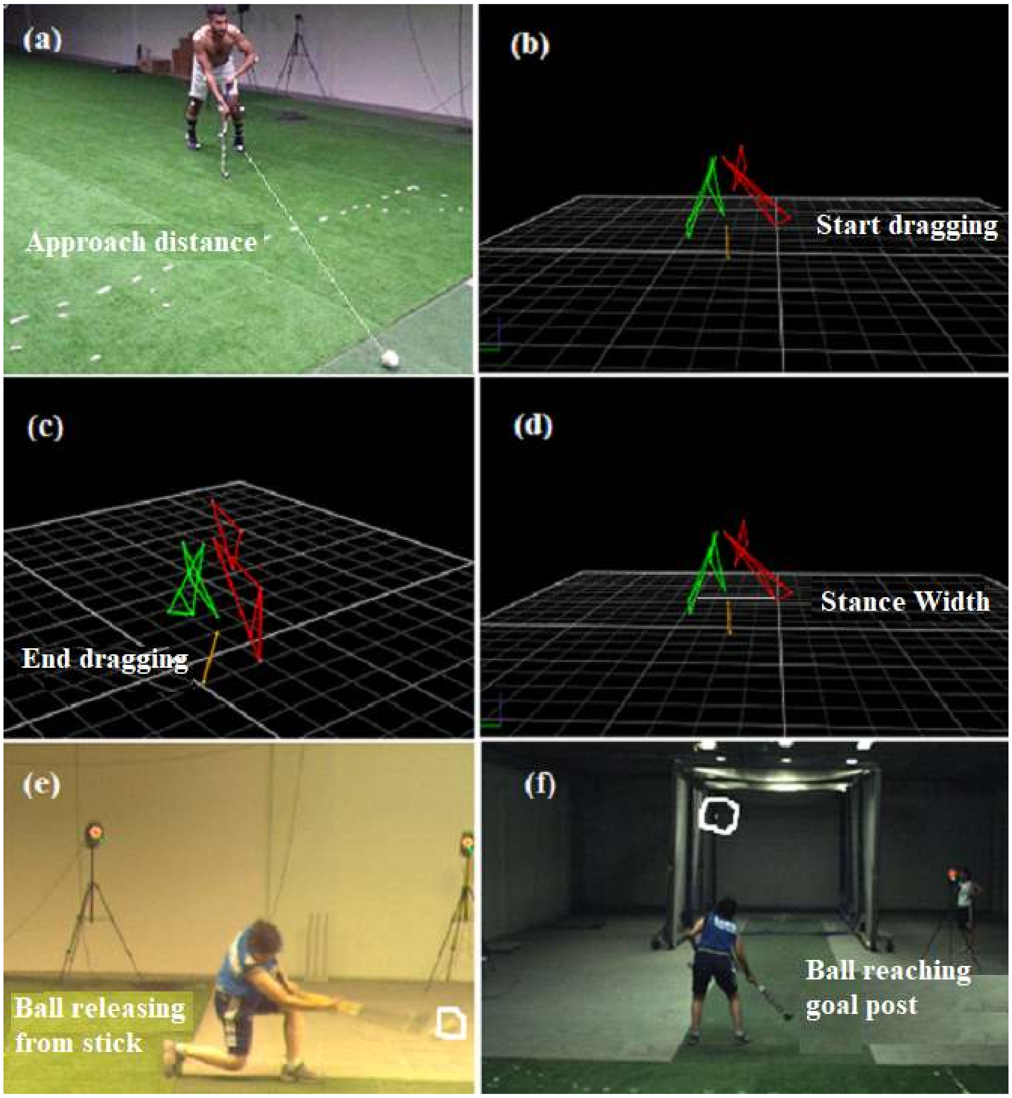

Figure 1. Screenshots of the Measurements of Kinematic Variables with the VICON System

(a)

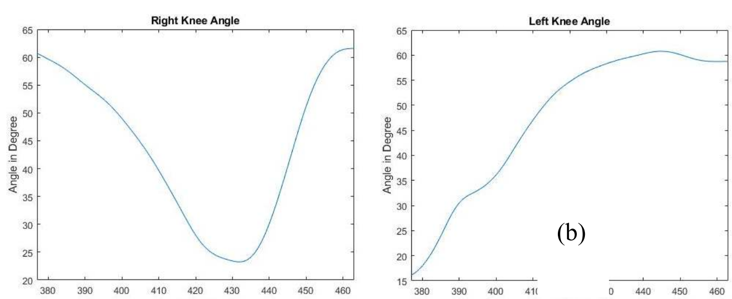

Figure 2. Knee Angles from Start Dragging to End Dragging

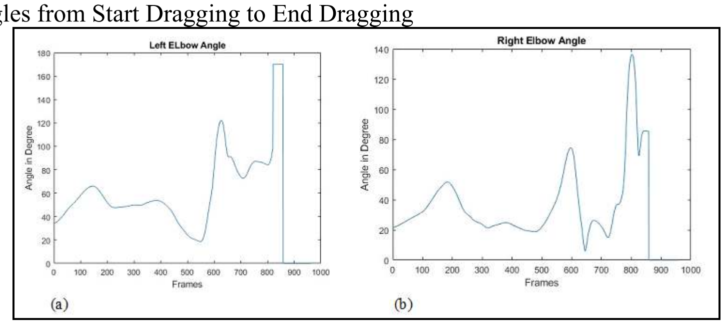

Figure 3. Elbow Angles from Start Dragging to End Dragging

Statistical Analysis

Descriptive statistics were used to explore the study variables, and Pearson correlation was applied to determine the relationship of kinematic and anthropometric variables with the ball velocity. Independent t-statistics was used to identify gender differences in kinematic variables. To measure the influence of kinematic and anthropometric variables on the ball velocity, multiple stepwise regression model was used because it allowed to measure the significance of each predictor separately. The level of significance was accepted at $p \leq 0.05$.

Ball Velocity = $\beta_0 + \beta_1$*(Approach Distance)* + β_2*(Drag Length)* + β_3*(Drag Time)* + β_4*(Drag Velocity)* + β_5*(Stance Width)* + β_6*(Left Knee Angle)* + β_7*(Right Knee Angle)*+ β_8*(Right Elbow Angle)* + β_9*(Left Elbow Angle)* + β_{10}*(Age)* + β_{11}*(Weight)* + β_{12}*(Height)* + *e* ***……. (Model)***

Results

The mean ages of the female and male players were 19.63 ± 1.90 and 20.25 ± 0.80, respectively; the mean weights were 49.00 ± 4.19 kg and 66.38 ± 4.92 kg, respectively; the mean heights were 149.91 ± 8.23 cm and 163.19 ± 7.57 cm, respectively.

The means, standard deviations, and results of independent t-test of the computed selected kinematic variables for gender group are presented in Table 1. The male players had significantly higher ball velocity (21.31 ± 3.53 vs. 15.10 ± 4.02 m/s), larger approach distance (3.05 ± 0.40 vs. 2.72 ± 0.38 m), wider drag length (2.15 ± 0.26 vs. 1.42 ± 0.33 m), longer dragging time (0.39 ± 0.05 vs. 0.31 ± 0.09 s), higher drag velocity (5.64 ± 0.61 vs. 4.69 ± 1.04 m/s), and larger stance width (1.27 ± 0.19 vs. 1.14 ± 0.15 m) compared to the female group. Furthermore, there were insignificant differences between the male and female groups in left–right knee and right elbow angles, while female group had larger left elbow angles (70.43 ± 11.50 vs. 58.47 ± 3.87 degrees) compared to the male group.

Pearson correlation coefficients are listed in Table 2. The obtained results show that the ball velocity had significant ($p < 0.05$) correlation with drag length (r = 0.70), drag time (r = 0.29), drag velocity (r = 0.59), stance width (r = 0.53), left knee angle (r = −0.33), right knee angle (r = −0.36), left elbow angle (r = −0.31), age (r = −0.32), weight (r = 0.36) and height (r = 0.39) of the player. While it had insignificant correlation with approach distance (r = −0.09), left knee angle (r = −0.33), and right elbow angle (r = 0.10) of the player.
Furthermore, it was also determined that age had significant ($p < 0.05$) correlation with approach distance (r = 0.46), drag time (r = 0.30), drag velocity (r = −0.40), right elbow angle (r = −0.36), and left elbow angle (r = −0.50). Weight also had significant ($p < 0.05$) correlation with approach distance (r = 0.46), drag length (r = 0.70), drag time (r = 0.54), drag velocity (r = 0.27), right elbow angle (r = −0.25), and left elbow angle (r = −0.58). It was also observed that height had significant ($p < 0.05$) correlation with drag length (r = 0.47), drag time (r = 0.42), stance width (r = 0.35), and left elbow angle (r = −0.59).

Stepwise multiple regression analysis was performed to determine the influence of the selected variables on the ball velocity, and the final results of the stepwise regression method are listed in Table 3. The change in R-square and F-statistic in Table 3(a) were significant and showed that the variable added in the step (model) significantly ($p < 0.05$) improved the prediction model. The value of R (0.91), multiple correlation coefficient, showed that the independent variables had a strong correlation with the ball velocity. The value of R-square (0.82) and adjusted R-square (0.80) described 82% variability in the ball velocity and can be explained by the fitted model.

The ANOVA results, F and p statistics, shown in Table 3(b) indicated that the overall predicted model was highly significant ($p < 0.01$). The regression coefficients, in Table 3(c), showed that the drag length (β = 4.63), stance width (β = 8.19), and height (β = 0.15) of the players had positive and significant ($p < 0.01$) influence on the ball velocity, while right knee angle (β = −0.07) and age (β_4 = −1.62) had inverse and significant ($p < 0.01$) effect on the ball velocity. The values of standardized coefficients showed that drag length had the most influential factor of the drag–flick performance in field hockey. The collinearity statistics showed that the independent variables in the final model had no strong correlation with each other. The predicted model for ball velocity with significant predictors can be expressed as:

Ball Velocity = 13.31 + 4.63 (Drag Length) + 8.19 (Stance Width) − 0.07 (Right Knee Angle) − 1.62 (Age) + 0.15 (Height)

Table 1. *Descriptive Statistics of the Kinematic Variables for Gender*

Variables	Gender	n	Mean	SD	t	p
Ball Velocity (m/s)	Female	32	15.10	4.02	−6.57	.000
	Male	32	21.31	3.53		
Approach Distance (m)	Female	32	2.72	0.38	−3.30	.002
	Male	32	3.05	0.40		
Drag Length (m)	Female	32	1.42	0.33	−9.93	.000
	Male	32	2.15	0.26		
Drag Time (s)	Female	32	0.31	0.09	−3.98	.000
	Male	32	0.39	0.05		
Drag Velocity (m/s)	Female	32	4.69	1.04	−4.44	.000
	Male	32	5.64	0.61		
Stance Width (m)	Female	32	1.14	0.15	−3.02	.004

	Male	32	1.27	0.19		
Left Knee Angle (degrees)	Female	32	54.75	17.42	0.87	.389
	Male	32	51.20	15.23		
Right Knee Angle (degrees)	Female	32	62.18	15.24	1.85	.069
	Male	32	55.78	12.20		
Right Elbow Angle (degrees)	Female	32	55.28	13.33	1.02	.314
	Male	32	52.78	4.00		
Left Elbow Angle (degrees)	Female	32	70.43	11.50	5.57	.000
	Male	32	58.47	3.87		

Table 2. *Pearson Correlation Coefficients*

Variables	Ball Velocity	Variables	Ball Velocity
Approach Distance	−0.09	Right Knee Angle	-0.36^{**}
Drag Length	0.70^{**}	Right Elbow Angle	0.1
Drag Time	0.29^{*}	Left Elbow Angle	-0.31^{*}
Drag Velocity	0.59^{**}	Age	-0.32^{*}
Stance Width	0.53^{**}	Weight	0.34^{**}
Left Knee Angle	−0.33	Height	0.39^{**}

**: Significant at the 0.05 level, **: Significant at the 0.01 level*

Table 3. *Results of Stepwise Regression Analysis*

3(a)-Model Summary

Model	**R**	**R Square**	**Adjusted R-Square**	**SE**	**Change Statistics**		
					R-Square Change	**F Change**	**p**
Final	0.91	0.82	0.80	2.17	0.04	11.06	0.001

3(b)-ANOVA

Model		**Sum of Squares**	**df**	**Mean Square**	**F**	**p**
Final	Regression	1,230	5	246	52	.000
	Residual	273	58	5		

3(c)-Regression Coefficients of the Final Model

Variable	**Unstandardized Coefficients**	**SE**	**Standardized Coefficients**	**t**	**p**	**Collinearity Statistics**	
(Constant)	13.31	4.84		2.75	0.01		
Drag Length	4.63	0.71	0.45	6.56	0.00	0.67	1.50
Stance Width	8.19	1.65	0.31	4.97	0.00	0.82	1.22
Right Knee Angle	−0.07	0.02	−0.19	−3.33	0.00	0.93	1.07
Age	−1.62	0.24	−0.49	−6.85	0.00	0.61	1.63
Height	0.15	0.04	0.31	3.64	0.00	0.44	2.29

***Predictors**: (Constant), Drag Length, Stance Width, Right Knee Angle, Age and Height; **Dependent Variable**: Ball Velocity*

Discussion

The purpose of this study was to determine the influence of the selected kinematic and anthropometric factors on the ball velocity of the drag–flick performance of the national elite players. The drag length, stance width, and height of the players had a significant and positive influence on the ball velocity, while average right knee angle and age had a significantly inverse effect on the ball velocity. Up to now, there have been no studies on significant kinematic factors and physical attributes of the player during the drag–flick performance in relation to the ball velocity.

This study identified a larger stance width for male group (1.27 ± 0.19 m) than that (1.23 m) reported by Ladro et al. (2019) but smaller than that (male = 1.55 m, female = 1.32 m) reported by Lopez de Subijana et al. (2010).

The average ball velocity determined in this study for male (21.31 ± 3.53 m/s) players was lesser than those (30.50 m/s and 31.85 ± 0.86 m/s) reported by Baker et al. (2009) and Husain et al. (2012), respectively. Similarly, Lopez De Subjina et al. (2010) has also reported larger velocities for male (21.9 m/s) and female (17.9 m/s vs. 15.10 m/s) groups.

Ladru et al. (2019) found that the ball velocity had a significant correlation with the angular velocity of the knee extension, drag length, and stance width. This study showed that drag length, stance width, and height of the player had a significant and positive influence on the ball velocity, while average right knee angle and age had insignificant and inverse effect on the ball velocity of the drag–flick performance.

Eskiyecek et al. (2018) discovered significant differences in the effect of right shoulder and angular speed of the left knee on the ball speed. They found that the ball velocity was affected by the angular velocity of the right elbow and the left hip. This study concluded that the ball velocity had significantly inverse correlation with average left elbow angle, while it had positive and insignificant correlation with right elbow angle. In addition, it was also determined that the average right knee angle had significant influence on the ball velocity of the drag–flick.

Palaniappan and Sundar (2016) identified that the drag length and distance of left foot from stationary ball had a significant effect on the ball velocity. This research confirmed that drag length was the most significant predictor of the ball velocity, and stance width had also a significant influence on the ball velocity. Ratko et al. (2006) reported that the elbow (angle) movement was important for an accurate drag–flick shot. It was also established that the extension of the elbow significantly increased the ball velocity of the drag–flick (Gürol and Yılmaz, 2016). This study found that the average left elbow and right knee angles had a significant association with the ball velocity.

Verma (2014) reported that physical variables (e.g., arm, shoulder, and grip strength) significantly contributed towards the drag–flick performance. This study also showed that the player's weight and height had a significant effect on the ball velocity of the drag–flick. Bari et al. (2014) also reported that the ball velocity had a significant correlation with dragging distance and shoulder orientation. This study confirmed that the ball velocity had a significant correlation with dragging length, dragging velocity, and stance width.

Conclusion and Recommendations

Ball velocity of the drag flick had a significant association with drag length, drag time, drag velocity, stance width, right knee angle, left elbow angle, age, weight, and height. In terms of gender, significant differences were found in the ball velocity, drag length, drag time, drag velocity, stance width, and left elbow angle. The drag–flickers attempted to obtain high ball velocity by maximizing the drag length and stance width and minimizing the right knee angle. The age and height of the players also had a significant effect on the ball velocity. In field hockey, the player's body movement in different planes with different angles affected the dynamics of the drag–flick. Therefore, drag length, stance width and height of the player are the key factors of the high ball velocity drag–flick. Thus, by considering the significant biomechanical and anthropometric factors during the training and competition, the drag–flickers will be able to improve their skills and performance.

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