3D BIOMECHANICAL ANALYSIS OF TARGETED AND NON-TARGETED DRAG FLICK SHOOTING TECHNIQUE IN FIELD HOCKEY

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Abstract

The aim of this study was to compare targeted and non-targeted drag flick field hockey shooting techniques in the penalty corner area, using a three-dimensional kinematic analysis. Eleven male field hockey players playing in the super league (mean age: 19,82±1,40 years) participated voluntarily. Seven high-speed cameras (Oqus 7+) with 120Hz refresh rates were used. Field calibration was completed via the wand method. The data were evaluated in two phases: start and finish. Players undertook three drag flick shots to the box using targeted and non-targeted techniques. The angular kinematics and stroke force applied to the stick were analyzed using the Qualisys Track Manager Program V2.12, and ball velocity statistics were gathered with the SPSS 18.0 program. To compare between the targeted and non-targeted shots of the drag flick shooting techniques, t-test was applied. At the drag flick of the players, significant differences were noticed at the angular speed of the right shoulder and the left knee, and the angular acceleration of the right hip in the starting phase, and also at the right hip angular acceleration at the finish phase. When the ball speed data considered, a significant decrease was observed between the targeted and non-targeted drag flick shots. Significant correlation was found out between some variables, at the angular kinematics and both force applied on the stick and the ball speed values ($p \leq 0.05$). In conclusion, to make an accurate target shot the players maximize their targeted shooting rates, particularly by decreasing the speed of their lower extremities.

Key words*: penalty corner, drag flick, kinematic, ball velocity*

Introduction

Field hockey is a high-intensity sport due to its multi-dimensional nature and has quite long-standing background (Sharma et al., 2012). It requires physical fitness, psychological skills, techniques, and strategies (Anders and Myers, 2008). There are various shooting techniques used in this sport. The drag flick shooting technique examined in this study is known as the highest-scoring technique in field hockey and the mechanics of each phase of the technique is significant in terms of performance (Bari et al., 2014b). This shooting technique is the most common offensive technique in both outdoor and indoor field hockey and is preferred for goal shooting. One of the most important technique of scoring penalty corner (Laird and Sutherland, 2003; Pineiro, 2008), and success depends on three main technical applications: pusher, stopper, and drag flicker (Lees, 2002). During a penalty corner, the drag flick is much more effective than the hits or pushes and is used more by male players than female players (Bari et al., 2014b). According to hockey rules (FIH 2009), there is no stipulation regarding the maximum and minimum height of the ball when the first shot at scoring a goal is a push or a drag flick (Bari et al., 2014a; Yusoff et al., 2008).

There is a need for biomechanical studies to develop well-targeted shooting techniques for drag flick shots made at the penalty corner. Most sports techniques were discovered in order to increase the performance or via trial and error in order to meet the needs of changing equipment or rules (Carr, 1997).

Biomechanical analysis is essential to find the key mechanical factors of physical performance (Gómez et al., 2012). Various biomechanical studies have been conducted on field hockey. Some researchers focused on shooting techniques (Chivers and Elliot, 1987; Kerr and Ness, 2006; Brétigny et al., 2008) and reviewed the biomechanical model of the drag flick in search of the best performance. In several studies, the kinematic data was provided about the drag flick and players of different levels (McLaughlin, 1997; Yusoff et al., 2008; López de Subijana et al., 2010).

All the angular movements of the joints must be evaluated correctly for the players to develop better performance in competitions and improve their current performance. As field hockey is a target-oriented sport, the criterion for evaluating performance is the ball reaching the goal post at the end. Ball velocity becomes significant at this point, because a high-speed ball gives a goalkeeper less time to save. Decreasing the speed of the joints is another method for targeting points the goalie will have difficulty meeting, thus increasing the goal rate.

The aim of this study was to compare the biomechanical characteristics of targeted and non-targeted drag flick shots made at the penalty corner. The secondary aim of the study was to understand the training strategies and methods of shots that applied on the penalty corner.

Methods

Participants
Eleven (N=11) male field hockey players (mean age±SD 19,8±1,4 years; mean height±SD 174,9±5,6 cm; mean weight±SD 70,1±8,0 kg) who represented Turkey's Men's National Hockey Team and Bolu Highway Hockey Club participated in this study voluntarily and were all informed about the study. No players had significant musculoskeletal injuries according to their recent medical histories. This study was approved by the Human Ethics Committee, University of Kocaeli, with the protocol code KOÜ KAEK 2015/173 and was conducted in a manner consistent with the recommendations of the declaration of Helsinki.

Design and Procedures
This study was experimental, so a 3D videography kinematic method was used for data collection. All players had approximately 20 minutes to warm-up, including running and dynamic exercises. Players used their own sticks (91cm long and 600gm average weight) and a white, rigid field hockey ball that weighed approximately 156-163gm.

12.5cm diameter reflector markers were attached to the players' joints: olecranon on the elbows; medial styloid on the wrists; acromion on the shoulders; trochanter major on the hips; patellar lateral condyle on the knees; lateral malleolus on the ankles; and also to the stick. The hockey ball was also covered by a reflective material for tracking.

Measures
The measurements were made with Qualisys Motion Analysis System software and seven high-speed 120 Hz video cameras (Oqus 7+) were used for recording the performance of the players (Figure 1). After placing the video cameras in the field, the calibration was carried out dynamically via the wand calibration method, using a 60.3cm long T-shaped calibration stick. A Sports Radar Gun (km.h^{-1}), Astro Products, CA was used to measure the velocity of the ball.

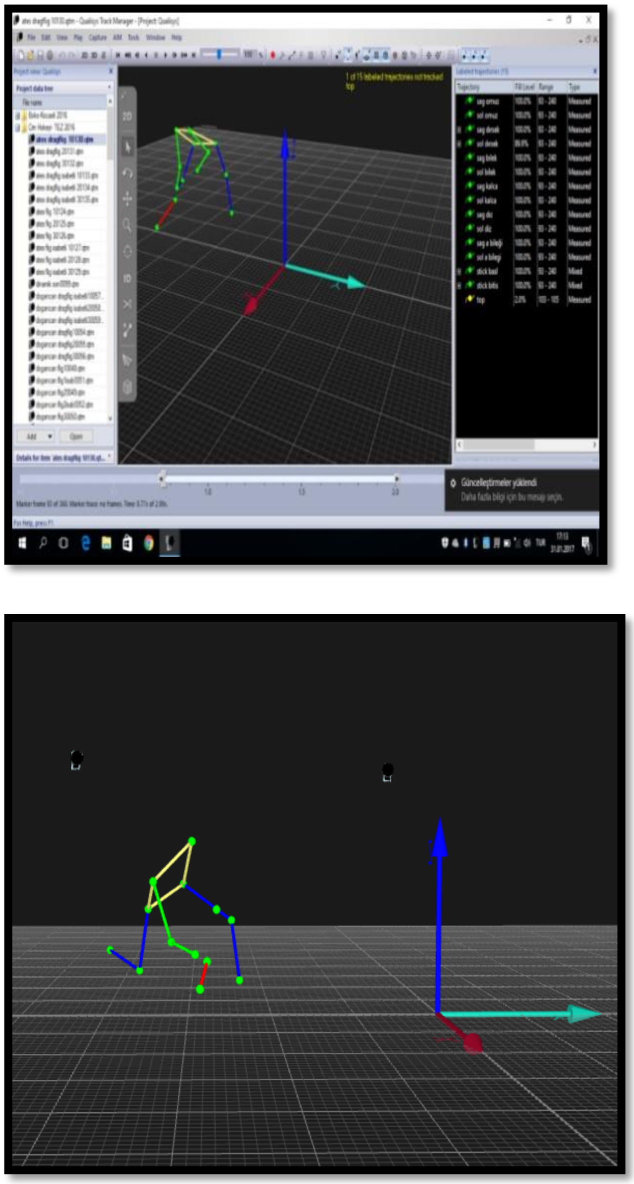

Figure1. A capture from Qualisys Track Manager software

The players performed six drag flick shots at a distance of 9.15m from the goal post. Three were targeted (at a 40x40 cm size, iron-framed panel attached in the middle of the crossbar) and three were non-targeted. Kinematic data figures obtained in the study used the moment when the left, supporting foot stepped on the ground as the starting phase and the moment the ball left the stick as the finishing phase. The hockey stick angles were taken on a YZ plane and the force variable was calculated with the formula $F=m\times a$ (force applied to the stick = weight of the stick × the acceleration of the stick at the finish).

Statistical Analysis
The descriptive statistics of the anthropometric parameters and the angular kinematic parameters were obtained by using SPSS 18.0 (SPSS Inc., Chicago, IL, USA) software program. The comparison between the targeted and non-targeted shots of the drag flick shooting techniques, t-test was applied. Besides, at the identification of the relation between the angular kinematic parameters and both the force applied on the stick and the ball velocity; Pearson Correlation test was applied on the data. The significance level was accepted as $p\leq0.05$.

Results

The kinematic figures derived from the 3D motion analysis of the players and the statistical definitions and comparisons of these figures, the results of the shooting force to the stick, and the ball velocity are presented as tables.

Table 1. Comparison of the angular kinematic values in the starting and finishing phases of the non-targeted and targeted drag flick shots (t test)

	Non-Targeted Drag Flick - Targeted Drag Flick			
	Mean±SD	**Mean±SD**	**t**	**p**
	Starting			
Right Shoulder Angular Velocity (°/s)	-238,22±145,97	-104,74±231,48	-3,300	,003*
Right Hip Angular Acceleration (°/s²)	5155,49±3273,36	1238,64±5990,57	3,492	,002*
Left Knee Angular Velocity (°/s)	-240,38±213,26	-159,2±263,91	-2,090	,047*
	Finishing			
Right Hip Angular Acceleration (°/s²)	-809,97±4489,09	-3014,65±3810,88	2,421	,024*

*p≤0.05

When Table 1 was examined, the verifications were: a negative decrease rate of %55 in the mean angular velocity of the right shoulder at the starting phase of the drag flick shots of the players (non-targeted shot: -238,2 ± 146,0 º/s; targeted shot: -104,7 ± 231,5 º/s) and a %34 decrease in the mean angular velocity of the left knee (non-targeted shot: -240,4 ± 213,3 º/s; targeted shot: -159,2 ± 263,9 º/s) and a positive decrease rate of %76 in the mean angular acceleration of the right hip (non-targeted shot: 5155,5 ± 3273,4 º/s^2; targeted shot: 1238,6 ± 5990,6 º/s^2). There were statistically significant differences found in the results ($p\leq0.05$). As for the finishing phase of the drag flick shots, a negative increase at the mean angular acceleration of the right hip (non-targeted shot: -810,0 ± 4489,1 º/s^2; targeted shot: -3014,7 ± 3810,9 º/s^2) and a statistically meaningful difference were found.

Table 2. Ball velocity figures measured by radar regarding the non-targeted and targeted drag flick shots

	Non-Targeted Drag Flick			Targeted Drag Flick				
Ball Velocity	**Min-Max**	**X**	**SD**	**Min-Max**	**X**	**SD**	**z**	**p**
km.h⁻¹	11-58	41,12	12,87	10-51	35,91	13,68	-2,606[a]	,009*
m.s⁻¹**	3,06-16,11	11,42	3,58	2,78-14,17	9,97	3,80		

*p≤0.05 ** 1 m.s⁻¹ = 3.6 km.h⁻¹

When Table 2 was examined, a %13 decrease was identified between the means of non-targeted (mean±SD 11,42 ± 3,58 m.s⁻¹) and targeted (mean±SD 9,97 ± 3,80 m.s⁻¹) drag flick shots in the ball velocity data. There was a statistically significant difference (p≤0.05).

Table 3. Comparison of the force applied on the stick at non-targeted and targeted drag flick shots

	Non-Targeted Drag Flick		Targeted Drag Flick			
	X	**SD**	**X**	**SD**	**z**	**p**
Force Applied on The Stick (N)	135,56	123,32	131,64	107,34	-1,193[a]	,233

*p≤0.05

When Table 3 was examined, there was no statistically significant difference found in the force applied to the stick between the mean of the targeted and non-targeted drag flick shots (p>0.05).

At the review of the correlation results in the study, a meaningful relationship was found between some of the variants at the angular kinematics and the ball velocity values. Accordingly, the ball velocity was affected by the angular velocity of the right elbow (r=,445) and the left hip (r=,449) and the angular acceleration of the right hip (r=-,452) and the trunk (r=-,506) at the starting phase of the players' non-targeted drag flick shots. During the finish phase, the angular acceleration of the right hip (r=,399), the left hip (r=,399), and the trunk angle (r=,404) affected the ball velocity (p≤0.05). During the starting phase of targeted drag flick shots, the angular velocity of the right hip (r=,401) and the trunk angle (r=,485) were found to affect the ball velocity (p≤0.05). No relationship was found between the ball velocity values and the other angular kinematics at the starting and finishing phases of the non-targeted and targeted drag flick shots (p≤0.05).

Meaningful relationship was found between some variables of the angular kinematics and the force applied to the stick. Accordingly, the kinematics affecting the force applied to the stick at the starting phase of non-targeted drag flick shots were: the angles of the right shoulder (r=,415), the right hip (r=-,427), the stick (YZ) (r=,556), the angular velocity of the right knee (r=,381), the left knee (r=,499), the right shoulder (r=-,403), the angular acceleration of the right elbow (r=,418) and the stick (YZ) (r=-,393). As for the finishing phase, the angles of the right shoulder (r=,455), the left knee (r=,387) and the left hip (r=-,376), the angular acceleration of the right shoulder (r=-,392), and the angular velocity of the trunk (r=,390) and the stick (YZ) (r=,495) were verified as affecting the force on the stick (p≤0.05). As with the targeted drag flick shots, the force on the stick was affected by the left knee (r=,521), the right hip (r=-,557) and stick (YZ) (r=,566) angles, the right knee (r=,694), the right shoulder (r=-,515) and the trunk (r=-,436) angular acceleration, the left hip (r=,474), the left knee (r=,746) and the trunk (r=-,571) angular velocity during the starting phase. At the finishing phase it was affected by the right shoulder (r=,680), the left hip (r=,460) and right knee (r=,603) angles, the right knee (r=-,714) and trunk (r=-,434) angular acceleration, and the left hip (r=-,455) and stick (YZ) (r=,724) angular velocity (p≤0.05). No relation was identified between the force applied to the stick and the other angular kinematics at the starting and finishing phases of the non-targeted and targeted drag flick shots (p≤0.05).

Discussion

The purpose of this study was to the compare the kinetic (force on the stick) and kinematic (angle, angular velocity, angular acceleration, and ball velocity) variations of targeted and non-targeted shots performed by elite hockey players, using 3D kinematic analysis of the field hockey drag flick shooting technique. A significant difference was found between the ball velocity of the non-targeted drag flick shots (11,42 m.s⁻¹) and the targeted drag flick shots (9,97 m.s⁻¹) (p≤0.05). A significant %13 decrease in ball velocity was observed during targeted drag flick shots ($p \le 0.05$), and this decrease increased the target rates.

In McLaughlin's 1997 study, he compared the values of fourteen male field hockey players to the values achieved by Australian field hockey national team member Greg Corbett. During the drag flick shot, the mean ball velocity (19.1 ± 1.84 m/s) when released from the stick surface is 15.2-21.8 m/s, while Corbett exhibited a ball velocity of 21.9 m/s at release. It was observed that, as the ball velocity decreased, the angular velocity of the shoulder increased and that of the hip decreased. The angular velocity of the hip and the shoulder affected the ball velocity.

Baker et al. (2009) measured the ball velocity values by radar and found ball velocity was 30.5 $m.s^{-1}$. Hussain et al. (2012) found ball velocity values during the drag flick shots of 31.85±0.86 m/s for college-level players and 30.99±4.33 m/s for those playing at the state level. There was no significant difference between the two groups ($p>0.05$). It was suggested that these insignificant ball velocity differences between the groups resulted from the increasing movement of the shoulder compared to the hip during oscillation. In a different study, Hussain et al. (2011) found that the ball velocity of players assessed in a body position of 45º and 90º during the execution of penalty shots on the upper right and left corners and in the right and left corner areas was between 25.42 $m.s^{-1}$-33.57 $m.s^{-1}$. Different levels of training affected the ball velocity.

Even though some researchers state there is no significant difference between successful and unsuccessful drag flick shots (Bari et al., 2014b), the study results suggested that the highest ball velocity ever reached made an important contribution to "scoring a goal" (Bari et al., 2014a). More velocity results in less time for the goalkeeper to save.

The conclusions of the study reported meaningful differences between targeted and non-targeted ball velocity values, and decreases in the ball velocity resulting in an increased the target rate, reflecting the results of our own study (Karadenizli, 2006). In Satti's 2004 study, conducted via kinematic analysis of targeted and non-targeted shots in basketball, air resistance and ball rotation had a slight effect and the angle and the velocity had to be in an appropriate combination vertically and horizontally (Gürol and Yılmaz, 2016). Ratko et al. (2006) found that the angle of the elbow movement is important for targeted and non-targeted shots. Miller and Barlett's 1996 demonstrated that the elbow extensors significantly contributed to ball velocity during the shot (Gürol and Yılmaz, 2016). Speed and accuracy are inversely correlated according to Fitt's Law; the faster the ball moves, the less accurate the shots are. Another factor affecting accuracy is the difficulty of the shot. In other words, the smaller an area the well-defended target has, the longer a distance it has. Thus, it can be concluded that speed and accuracy do not correlate and other strategies may be required while carrying out the motor tasks. Furthermore, as the target width decreases the necessary time for the motion increases (Karadenizli et al., 2014).

Jennings et al. (2010) reviewed the forces between the stick, the ball on the stick, and the position of the ball. It was verified that the normal force between the ball and the stick decreased while the ball was moving towards the stick head during the shots. During a drag flick shot, the force applied and the position of the ball was significant in controlling the drag flick shot.

According to our evaluation results, there were significant differences between the angular velocity of the right shoulder, the left knee, and the right hip at the starting phase of targeted and non-targeted shots. At the finishing phase, this difference was only present in the angular acceleration of the right hip ($p<0.05$).

Although significant differences were not encountered in the value of the left knee angle (non-targeted: 145°; targeted: 144°), the right knee angle (non-targeted: 116°; targeted: 114°) at the starting phase of the drag flick shots and at the finishing phase ($p>0.05$) showed similarities with those of Chivers and Elliott (1987) (150°) and López de Subijana et al. (2010) (male group: 156°-114°). Thus, the players moved with similar knee joint angles during the drag flicks.

Ibrahim et al. (2017) found that body axial rotation and lateral rotation towards the target, right wrist flexion, and left wrist extension are the main contributors to the speed of the stick head. They advised coaches to emphasize trunk rotations and wrist flexion and extension movements to maximizing stick head speed.

Initially, there is a backward oscillation of the arm during the low shots. During this oscillation, the shoulder rotates externally with abduction, in a position of humerus level with the shoulder. The flexor and internal rotator muscles that stretch during this movement pull the humerus down towards the front of the body. To perform an ideal drag flick shot from this body position, the players in our study demonstrated a decrease in angular velocity at %55 in their right shoulder flexors at the start of the drag flick shot and a decrease in the angular velocity at %34 in the left knee while making a knee flexion in addition to external rotation at the flexion position ($p \le 0.05$). At the start of the drag flick shot, a decrease of %76 at their angular acceleration of the right hip and an increase at the angular acceleration of the left hip was reported for the finishing phase ($p \le 0.05$). Consequently, an effective and targeted drag flick shot required a decrease in the angular acceleration of the right hip by placing it in an external rotation position as horizontal as possible at the start of the low shot. At the finish, there was a need for increased angular acceleration via the hip rotation and placing the left foot in a position vertical to the shooting line.

Recommendations

The biomechanical studies performed in different branches mention about negative relationship between speed and hit. Whereas an accurately directed quick shot allows less time to goalkeeper to save the shot; hence it is important. Different movements of the player's different body parts in different planes affect the shooting dynamics. Therefore, identification of correct body positioning is a prior need. As a result, by determining the key elements and correcting them with players, it would be possible to improve the shooting performance.

By incorporating more target-oriented exercises in their training and repeating them frequently, coaches will be able to prevent their players' speeds decreasing during targeted shots. This will increase the players' skills and improve performance during high-accuracy shots. Furthermore, identification of the shooting dynamic variances and discovery of the key kinematic elements affecting the shooting dynamics contributes a great deal to sports scientists and coaches in terms of comprehending shooting dynamics.

Conclusion

In order to execute accurately-targeted shots during the application of the drag flick shooting technique, the players in this study tried to maximize their performance by decreasing their speed both in their lower extremities and in their ball velocity.

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3D BIOMEHANIČKA ANALIZA TEHNIKA GAĐANJA U HOKEJU NA TRAVI

Sažetak

Cilj ove studije bio je usporediti ciljanu i neciljanu tehniku gađanja u hokeju. na terenu u području kaznenog kuta pomoću trodimenzionalne kinematske analize. Na uzorku od jedanaest muških hokejaških igrača koji su igrali u super ligi (srednja dob: 19,82 ± 1,40 godina). Upotrijebljeno je sedam kamera visoke brzine (Oqus 7+) s frekvencijama osvježavanja od 120 Hz. Kalibracija polja dovršena je metodom štapića. Podaci su ocijenjeni u dvije faze: početak i završetak. Igrači su napravili tri gađanja pomoću ciljanih i neciljanih tehnika. Kutna kinematika i udarna sila primijenjena na štapiću analizirani su pomoću programa Qualisys Track Manager V2.12, a statistički podaci obrađeni su pomoću programa SPSS 18.0. Za utvrđivanje razlika između dviju tehnika korišten je t-test. Uočene su značajne razlike pri kutnoj brzini desnog ramena i lijevog koljena, a kutna ubrzanja desnog kuka u početnoj fazi, a također i na desnom kutnom ubrzanju kuka u završnoj fazi , Kada se uzmu u obzir podaci o brzini loptice, zabilježeno je značajno smanjenje između ciljanih i neciljanih snimki zujanja. Značajna korelacija je otkrivena između nekih varijabli, kod kutne kinematike i obje sile primijenjene na štapiću i vrijednosti brzine loptice ($p \leq 0.05$). Zaključno, kako bi se postiglo precizno gađanje, igrači maksimiziraju svoje ciljane brzine snimanja, osobito smanjujući brzinu njihovih donjih ekstremiteta.

Key words: *kazneni udarac, kinematika, brzina loptice*

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