Trakia Journal of Sciences, Vol. 19, Suppl. 1, pp 663-670, 2021
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Available online at:
http://www.uni-sz.bg

ISSN 1313-3551 (online) **doi:10.15547/tjs.2021.s.01.102**

KINEMATIC STRUCTURE AND CHARACTERISTICS OF THE "DRAG FLICK" FIELD HOCKEY TECHNIQUE

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ABSTRACT
"Drag flick" is a modern technique of pushing in field hockey, developed and implemented in the game practice in the early 90s of the last century. The technique is designed for shooting, mainly in the execution of a penalty corner, where the efficiency (success rate) varies between 40-60%. In Bulgaria, these values range between 20-30%.
PURPOSE The aim of our research is to reveal the phase structure of the "Drag Flick" (DF) technique during the execution of a penalty corner, as well as to provide a kinematic characterization of the main moments and phases of the movements of the body and the stick. The realization of the goal requires the solution of the following important tasks: biomechanical analysis of the DF technique and determining the key moments and phases of the movement of the body and the stick in space, considering the geometry of the boundary interphase positions.
METHODS The subject of the study were a total of 10 hockey players – goal scorers and performers of penalty corners, considered to be top specialists in DF technique.
In our research, we used the following methods:
• Observation;
• Video recording;
• Video-computer analysis of technical actions;
• Analysis of videograms and kinograms composed of the boundary positions between the different phases in the implementation of the DF.
RESULTS: Our analyses have shown that the take-off speed of the ball is influenced to the greatest extent by the magnitude of the force impulse received during the joint movement of the stick and the ball in the executive phase. Second in importance is the path length of the stick and the ball, from the moment of contact to the moment of separation.
CONCLUSIONS: The DF technique in the execution of a penalty corner goes through three phases: preparatory, executive, and final. The overall movement is realized by performing at least 6 steps – 2 or more accelerating ones, a rotary step, a back cross step, an executive step and finally – a support step on the right foot. The described 14 moments reflect the motor structure underlying the DF technique.

Key words: Biomechanics, Field Hockey, Drag Flick, Penalty Corner, Technique, Phase structure, Kinematic

INTRODUCTION

Drag flick (DF) is a modern pushing technique that emerged in the game of the leading hockey nations in the early 90s of the last century, as a result of the introduction of biomechanical research in order to modify and improve the classic flick. A number of authors have defined DF as an effective technique for shooting when executing a penalty corner (PC), with an efficiency coefficient (EC) varying in the range between EC 0.3-0.6 (30-60%) According to López de Subijana et al. (1), DF is between 1.4 and 2.7 times more efficient than hitting or push-shooting the ball towards the goal when executing a penalty corner. These results have been confirmed by other researchers (2-8, 10-20).

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Having examined relevant contemporary scientific reports and publications for the purposes of the present research, we have taken into considertion a significant number of studies on DF, including biomechanical analyses, methods for planning and improving the technique of execution regarding the speed of the ball, the accuracy of shooting the ball, etc (1-20).

Experts have identifed three decisive factors determining the effectiveness of striking, including in using DF when executing a PC, namely: speed of the ball, accuracy, and feint movements (3, 4, 17, 20). According to Antonov, A. and S. Chavdarov (4), the effectiveness (efficiency) of the overall execution of the penalty corner does not depend only on these three factors of shooting with DF technique, but is also correlated with other indicators, as follows:

1. The accuracy of the ball passed from the end line;
2. The speed of the ball passed from the end line;
3. The minimal loss of time for stopping the ball outside the circle, the timely and convenient passing to the striker performing a DF– as a consequence of the previous two factors;
4. Difficult conditions for direct striking with DF – as a consequence of the previous three factors.

Biomechanical studies characterizing the phase structure of the drag flick which reveal the time moments and the forces with an impact on the kinematic chain would optimize the development of the technique and the methodology of training of elite performers (1, 2, 6-8, 12, 14-16, 18-20). The correct positioning and timely corrections in the trajectory of the acceleration of players performing DF prior to their contact with the ball could compensate to some extent the problems defined by Antonov, A and S. Chavdarov (4) regarding the accuracy of passing and stopping the ball. Scientific publications focusing on the biomechanical structure of the executive phase of DF are undoubtedly useful; however, research on the overall kinematic chain and dynamic characteristics of the “body-stick” system – from the moment of the player’s positioning to the moment of establishing a balanced position on two support legs – can provide a much more detailed picture and answers to key questions related to the evolution of the DF technique.

PURPOSE

The aim of ourstudy is to reveal the phase structure and development of the DF shooting technique, to characterize the key motor moments of the “body-stick” system, and to report the presence of different styles – modifications of the technique.

The set aim of the study requires the realization of the following **tasks**:

1. Qualitative biomechanical analysis of the DF technique.
2. Determining the key moments and phases of the movement of the body and the stick in space, based on the geometry of the moment boundary interphase positions.

METHODS

The subject of observation and research were 12 athletes, elite performers of PC in Bulgaria and abroad: Bulgarian – 2 (SCh and RG), Dutch – 2 (TT and MVdW), English – 2 (CG and AD), German – 2 (CZ and MF), Argentian – 1 (GP), Indian – 1 (SS), Pakistani – 1 (SA), and South African – 1 (JRR).

The main focus of research was the kinematic phase structure of the DF technique in the execution of a PC.

The following methods were used:

- Observation;
- Video recording;
- Video-computer analysis of the technical actions;
- Analysis of videograms and kinograms composed of the boundary positions between the different phases in the execution of DF.

RESULTS & DISCUSSION

The present study aimed to reveal key moments of the phase structure of the implementation of the DF technique, through observation, video recording and analysis of videograms and kinograms composed of the boundary poses between the different phases – preparatory, main (executive) and final. Previously, Antonov, A. et. al. (2) identified the main initial and final moments in the phase structure of the DF. The authors came to the conclusion that in the early years of the development of the DF technique (i.e., from the 1990s until the beginning of the new millennium), the latter evolved into two main variations (2). Both are executed within six steps.

The first variation of the DF technique, more often used by Europeans, is characterized by the fact that the moment of contact between the stick and the ball takes place during the rotational step. In the second variation, more commonly used by Asian competitors and well established in the last decade, the moment of contact occurs during the back cross step (2).

In the available literature, we can find a number of studies focusing on particular moments of the kinematic structure of DF. Notably, Antonov, A., et al. (2), Palaniappan R., V. Sundar (15) and Ladru B. J. et al. (20) have attempted to provide a comprehensive biomechanical characteristic of the "body-stick" kinematic system as well as a description of the main moments of the phase structure of the technique. Palaniappan R., V. Sundar (15) defined the following four phases: approach, contact, drag, and follow through. Ladru B. J. et al. (20) also defined four phases: running-up, pre-stretch, acceleration, and follow through. According to Antonov, A., et al. (2), the kinematics of movement of the body and the stick in a DF include three phases – preparatory, executive, and final.

Preparatory phase
European style – starting position, start and acceleration
Asian style – starting position start, and acceleration, rotation of the left support leg (rotational step), back cross step

The preparatory phase starts from the moment of starting towards the ball. The initial position of the competitor before the actual start is with separated legs in the sagittal plane – one placed forward of and the other – behind the torso, depending on the number of acceleration steps – even or odd. The toe of the stick is in touch with the ground and the stick acts as a third fulcrum, which increases the support area and improves the geometric stability of the competitor-stick system. Some players also make a start from a position with legs placed in the frontal plane, separated sideways, which allows faster correction in positioning and effective execution of the preparatory phase, even in case of inaccurate passes and stops of the ball **(Picture 1).**

Picture 1. Starting position for DF when performing a PC

When using an even number of acceleration steps, the start begins with the left foot. The first two accelerating steps on the left and right support legs are followed by a third (rotational) step that passes through the support of the left leg as the athlete places the foot at an angle of 45° to the direction of movement and allows active rotation of the body from the frontal to the sagittal plane. The rotational step prepares the athlete to perform the fourth step – back cross.

The first three steps are performed with uniform acceleration. The acceleration of the competitor is executed at optimal speed, along a trajectory consistent with the direction of the movement of the ball and the position of the player who stops it. After stopping the movement of the ball, the forward performs the rotational **(Picture 2)** and the cross step (**Pictures 3 and 4**)

Picture 2. Preparatory phase – a rotational step on left support leg

Picture 3. Preparatory phase – start of a cross step

Picture 4. End of the cross step and start of the execution phase

As a result of these actions, the striker assumes a body position in profile regarding the goal. The left shoulder is the leading one. At any moment of the preparatory phase, the stick moves along the ground. At the start, it is directed forward, and from the moment of performing the rotational step, it starts being left behind the body.

When performing the back cross step, the competitor's speed slows down due to the rotation of the body. The stick stays behind the support left leg at a distance of 0.5 – 1 m, depending on the anthropometric profile of the athlete **(Picture 4).**

The preparatory phase of the DF pushing technique when performing a PC ends at the moment of contact of the stick and the ball located at a playing distance behind the body.

In Photos 2-4, following the preparatory phase in the execution of DF by SA from Pakistan, the latter representative of the Asian school makes contact with the ball during the cross step. Most European athletes make their first contact with the ball at the beginning of the rotational step.

Executive phase
European style – rotation of the left support leg (rotational step), back cross step, joint movement of the stick and the ball – contact, dragging and flicking, followed by a separation of the ball
Asian style – joint movement of the stick and the ball – contact, draging and flicking, followed by a separation of the ball

Picture 5. Execution step and starting moment of dragging the ball

The executive phase of the DF technique includes two parts – unloading, which is observed in the rotational and the back cross step, and loading, which is observed in the execution step. The unloading of the support, whereby inertial forces change the direction of their action downwards, leads to an increase in the force impulse and the acceleration of the stick and the ball along the trajectory. The rotational and the cross step create the necessary conditions for dragging the ball so that the support (right) foot is located significantly in front of the ball (0.5 – 1 m) in the direction of shooting **(Pictures 4 - 5)**. In the studies of Palaniappan R., V. Sundar (15), the distance between the right foot at the support of the cross step and the first contact with the ball is 0.69 +/- 0.11m.

The long execution step leads to a lower common center of gravity, with downward acceleration. The resulting inertial force is directed to the support of the right leg, which leads to a moment of loading of the support and an increase in the normal pressure of the body – N. This reduces the friction forces, contributes to a significant easing of the mechanical conditions and increases the amplitude of the movement of the body and the stick in dragging and pushing to the line of the front (left) foot **(Picture 6).** The length of the execution step is on average 1.37 m, SD + 0.08 m according to Palaniappan R., V. Sundar (15), 1.42 m according to McLaughlin (8) and Bari et al. (6), 1.51 m according to Subijina et al. (1), and 1.5 m to 1.81 m according to Yusoff et al. 2008 (12).

The lifting of the stick and the ball from the ground occurs at the moment of crossing the line of the heel or the toes (depending on the direction of shooting) of the front left foot. The trajectory of the stick and the ball after lifting, until the moment of separation, resembles the movement of “a whip”. It is significantly shorter than the path of dragging and pushing. The equal acceleration of the stick and the ball in the elite competitors from the moment of contact, dragging and flicking the ball to the moment of its separation from the stick is in the range of 2.00 – 3.00 m (1). In their research, Palaniappan R., V. Sundar (15) established a mean value of 2.31 m, SD + 0.66 m; according to McLaughlin (8), this value is 2.18 m., while according to Ladru B. J. et al. (20), this value is 2,22 ± 0,15 m (F) 2,73 ± 0,32 m (M), and according to Bari et al. (6), the distance passed during the contact between the ball and the stick in the executive phase of DF is 2.30 m.

Using the formula for the kinetic energy and the muscular force of the performer acting in the direction of the ball path $Fm.s=\frac{m}{2}.v^2$, we can establish the parameters influencing the obtained speed of the ball at the moment of its separation from the stick.

1.Fm – muscle force applied by the joint movement of the stick and the ball during dragging and whip-like pushing;
2. s – length of the path of movement of the stick and the ball during the executive phase;
3. m – mass of the ball – 0.160 kg;
4. v – take-off speed of the ball.

$$V = \sqrt{2} \,.\, Fm \,.\, s \,.\, \frac{\cos\alpha}{m}$$

Picture 6. End of the execution step and start of the push
6-A. SA – side view; **6-B.** TT – front view

Our biomechanical analysis has shown that the take-off speed of the ball is influenced to the greatest extent by the magnitude of the force impulse received during the joint movement of the stick and the ball during the executive phase. Second in importance is the path length of the stick and the ball, from the moment of contact to the moment of separation.

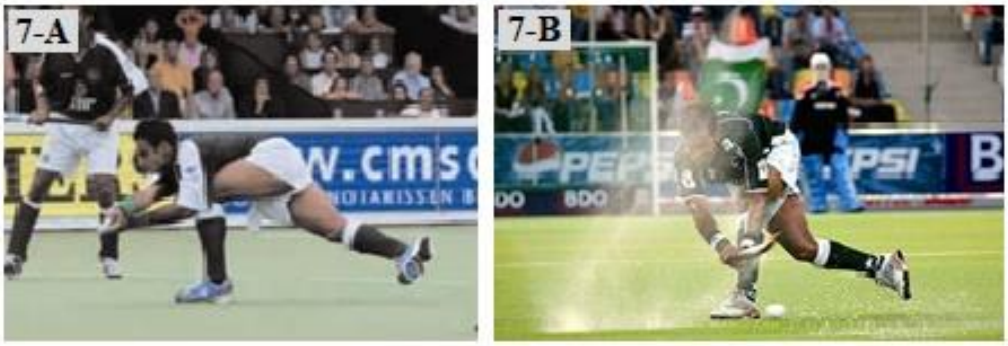
According to literature (2, 14) and our data, the initial take-off speed of the ball during the performance of DF by elite athletes is in the range of 30-34 m/s. The take-off speed of the ball in the elite performers of the DF is higher than the initial speed established by a number of researchers for the less qualified competitors, with values of 28.65 ±1.69 m/s reported by Rajinikumar Palaniappan1 and Viswanath Sundar (15), 19.6 to 27.8 m/s reported by Yusoff et al. (12), 15.2 to 21.8 m/s reported by McLaughlin (8), 24.9 ± 0.9 m/s reported by Cristina López de Subijana et al. (1), 25,42 to 33,57 m/s reported by Hussain et al. (18), 19,50 ± 2,18 m/s (F) 25,62 ± 2,18 m/s (M) reported by Ladru B. J. et al. (20).

In the execution step, the moment of the support of the left foot is of particular importance for the placement of the shot and the maintenance of balance after the separation of the ball. The foot must be placed in the direction of the push, i.e. “open” **(Pictures 6 and 7).** Often, inexperienced athletes “close” the foot – they place it perpendicular to the direction of shooting, which disturbs the kinematics and balance of the body at the end of the execution and during the final phase of the movement when the athlete must maintain the balance of the “body-stick” system.

Final phase

Closing and swinging the stick to the left, while simultaneously twisting and untwisting the swinging right foot arond the support left foot in *order to resume quickly the balance of the "body-stick" system and assume a stable position for the striker.*

With the separation of the ball, the stick is closed with its front surface to the ground and is swung to the left. Its height (distance from the ground) depends on the trajectory of the ball and the amplitude of the pushing force applied. Simultaneously with the swinging of the stick, the right leg begins swinging to the right, while the support is on the left leg.



Picture 7. Final phase – swinging of the stick and the right, swinging leg to the left (twisting around the support left leg)
7-A. Side view; **7-B.** Front view

Picture 7-A and 7-B show the transfer of body weight onto the front left leg and the subsequent twisting due to the opposite movement of the stick and the body. By inertial forces, twisting allows the body to maintain its balance in a single-support position.

At the moment of maximum twisting of the body and the stick **(Picture 7-A)**, the opposing inertial forces allow the right leg, the shoulder girdle and the stick to start an opposite movement – untwisting and the body to achieve balance through a double-support position **(Picture 8)**.

Picture 8. Untwisting to a balanced position on two support legs

CONCLUSION

The revealed phase structure and the description of the key moments of the movement of the body and the stick in space during the performance of DF give us reason to make the following **conclusions and recommendations** for sports-pedagogical practice concerning the training of highly qualified competitors.

1. The DF technique when performing a PC includes three phases – preparatory, executive and final and is realized through the implementation of six steps – two acceleration ones, a rotational, a back cross, an execution and a final one. The described 14 moments reflect

the motor structure which is the basis for the development of the DF technique.

2. Depending on the style, the **preparatory phase** involves two or three acceleration steps. The athlete must develop optimal speed and the right approach to the ball. Special attention should be paid to the speed of the transition from acceleration to rotational and cross step.

3. The **executive phase** comprises two parts – unloading and loading. Depending on the style, it goes through two or three steps with a total of five or six key moments in the movement of the body, the stick and the ball. In this phase, maximum power of movement is generated by applying several forces. The muscular forces of the lower limbs, the force of gravity, the muscular forces of the shoulder girdle and the torso provide the pulling force and develop the twisting reflex of pulling in the rotation of the shoulder girdle and the amplitude movement of the stick.

4. The additional moment of dragging, which appears in the loading phase, contributes to a significant increase in the path length of the stick and the ball and their uniform acceleration, and hence, to the speed of the ball after separation from the stick.

5. The speed of the ball in the execution of DF depends on the rational motor actions – maximum length and accelerating movement of the execution step, leading to an increase in the force impulse.

6. The twisting of the right leg, the shoulder girdle, the arms and the stick in the single-support position on the left leg allows maintaining the balance in the **final phase** of the movement and subsequent untwisting of the body.

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