IMPLICATION TO PERFORMANCE AND INJURY RISKS: THE KINEMATICS AND KINETICS INVOLVED IN THE EXECUTION OF THE DRAG FLICK BETWEEN ELITE AND SUB-ELITE FIELD HOCKEY PLAYERS

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The main objective in field hockey is to score in order to win and the most efficient technique utilised to score is the drag flick. This study aimed to analyse the drag flick motion to better understand the kinematics and kinetics involved in attributing to performance and injury risks. One world class elite athlete and three sub-elites athletes were recruited in which they performed a series of drag flick shots. A 12-camera VICON MX camera and one Kistler force plate were used to determine the variables of interest. There was a reduction in pelvis range of motion and angular velocity from proximal-to-distal segments, and an increased internal rotation moments for the sub-elites compared to the elites. This is indicative of a lack of technique proficiency and increased risk of injury at the hip which can be improved by targeted training and strength and conditioning.

KEYWORDS: DRAG FLICK, KINEMATICS, KINETICS, INJURY, RISK REDUCTION.

INTRODUCTION: The primary objective in field hockey is to score in order to win. As such, a penalty corner provides the prime opportunity for scoring a goal and following the 'kinetic link principle'; optimal proximal-to-distal sequencing of limb contribution to the execution of movement, will improve the teams' chances of scoring (Ibrahim et al. 2017). Given the ball is directed on target, the only means to improve the chance of scoring is to increase the velocity of the ball. The action of dragging the ball on stick through an accelerated release, better known as the drag flick, generates greater ball velocity than that of a hit shot which involves shorter stick and ball contact time (McLaughlin 1997). This drag flick technique is performed in a closed kinetic chain that progresses through a timely contact of the ball with a coordinated kinematic sequencing from proximal-to-distal limb (Ibrahim et al. 2017). Previous research (McLaughlin 1997; López de Subijana et al. 2010; Ibrahim et al. 2017) have investigated the kinematic sequencing of the drag flick and reported that the sequencing of angular velocity from proximal-to-distal segments flows through from the pelvis to the trunk followed by the shoulder and finally the wrist. This optimal kinetic sequencing of proximal-to-distal segment help generate momentum through to the hockey stick which is directly associated with maximal resultant ball velocity (Barlett 2007). Most of the previous studies have focused on the kinematic analysis of the drag flick and only a few have investigated the kinetic profile following the execution of this technique (López de Subijana et al. 2010; Ng et al. 2018). Ng et al. (2018) found that the drag flick resulted in a greater lateral trunk flexion and lumbar rotation compared to the traditional hit shot. In addition, Ng et al. (2018) reported that loading of the hip and lumbar spine is significantly increased in drag flicking compared to the hit shot. At present, no studies have investigated the kinematics and kinetics of the drag flick between elite and sub-elite athletes to shed light on the implications of performance assessment and injury risks between the two groups. Therefore, the main aim of this study was to examine the drag phase motion during ball contact to after ball release (follow-through) to better understand the kinematics and kinetics involved in attributing to performance and injury risks between a world class elite field hockey player and the sub-elite athletes. It is expected that the elite athlete would exhibit larger angular velocities at each segment, and improved motor-control and strength throughout the drag flick phase as compared to the sub-elite athletes.

METHODS: Four male participants all right hand dominant; one elite-level international calibre athlete (28 years old; 83 kg; 179cm) and three sub-elite national athletes (23 ± 2 years old; 76 ± 7 kg; 175 ± 2 cm) field hockey players were recruited for this study. The elite athlete is considered one of the top drag flickers during the period of data collection and was a part of

the Dutch national team that won silver at the 2012 London Olympics and gold at the 2017 European championship. The sub-elite athletes were on the Singapore national field hockey team. All participants were informed as to the nature of the study and a written consent was obtained. All participants underwent one testing session at the sport biomechanics laboratory at the Singapore Sport Institute (Singapore) with an experimental space of 15m x 10 m covered by artificial hockey grass. Prior to data collection, 72 retro-reflective markers were affixed to the participants' trunk, upper and lower limb with the requirements of the University of Western Australia model (Besier et al. 2003; Reid et al. 2010). A 12-camera VICON MX 3D motion analysis system (VICON Peak, Oxford, United Kingdom) sampling at 250 Hz and one Kistler force plate sampling at 2000 Hz (900 mm x 600 mm: Kistler Holding AG, Winterthur, Switzerland) were used to determine the kinematics and kinetics of the drag flick.
The participants performed a specific warm up routine which included running and dynamic stretches followed by task familiarisation of 10 drag flick shots towards the goal using their own hockey sticks. Following the warm up, each participant was instructed to approach the stationary ball located 15m away from the goal with a run up at a self-selected pace and performed a drag flick as fast and accurately as possible. A trial is deemed to be successful if the shots went in the goal and the front (left) foot making complete contact on the force plate. A total of six successful trials were analysed for each participant. Raw marker trajectory data was visually inspected and labelled in VICON Nexus software. Cubic spline interpolation was used to fill any gaps related to broken or missing marker trajectories. A residual analysis was performed using customized MATLAB software (The Mathworks, Natick, Massachusetts, USA) in order to determine the optimal filtering cut-off frequency for each individual marker. All marker trajectories and ground reaction force data were then filtered using a fourth-order, 10-Hz zero-lag low-pass Butterworth filter. Kinematic and kinetic outputs were obtained using a customised model (Besier et al. 2003) in the VICON Nexus pipeline. External joint moments were calculated by standard inverse dynamics as outlined by Besier et al. 2003. Output of discrete values and temporal normalization of waveform data of the drag flicking trials were done using a custom MATLAB program. Maximum velocity of the stick was determine by the resultant velocity of the marker placed at the end of the stick shaft. Data were time normalized to 101 time points as a percentage of the drag flick cycle; from ball contact to left foot off force plate. Joint moments and joint powers were normalized by bodyweight. Statistical analysis was performed using IBM® SPSS® Statistics 21 (IBM Corporation, Armonk, NY, USA). A one sample t-test was conducted to determine any significant differences in angular velocity and left hip moments between the elite and sub-elite athletes.

RESULTS: Presented data includes descriptive comparison between the means of the discrete variables together with their standard deviations between the elite and sub-elite athletes. Waveform data of the left hip kinematic and kinetic constitutes the best representative trial for the elite and one sub-elite athlete. Time is expressed as a percentage of foot contact; left foot strike to left foot off the force plate. The sub-elites exhibited a significantly reduced range of motion (ROM) at their pelvis throughout the drag flick (110.68 ± 9.39°) as compared to the elite athlete (135.45 ± 5.61°), t(2) = -7.99, *p* = .015 (Table 1). The maximum angular velocity from proximal-to-distal segments at ball release are smaller in the sub-elites compared to the elite athlete (Table 1). Specifically, there is a significant difference observed for right shoulder flexion angular velocity between the sub-elites (486.46 ± 200.48 °/sec) and elite (927.57 ± 111.39 °/sec), t(2) = -4.99, *p* = .038 (Table 1). The sub-elites displayed a significant reduction in maximum linear stick velocity (17.87 ± 0.66 m/s) at ball release compared to the elite athlete (20.15 ± 0.53 m/s), t(2) = -50.91, *p* = .000 (Table 1). Maximum hip extensor and adductor moments were similar for both group of athletes (Table 1). However, descriptively, the maximum hip internal rotation moment was larger in the sub-elites (-2.14 ± 0.59 Nm/kg) compared to the elite athlete (-1.45 ± 0.24 Nm/kg) (Table 1 and Figure 1). Hip internal rotation angle was larger in the sub-elite in the initial phase of foot contact (0-20% of foot contact phase) compared to the elite athlete (Figure 1). Peak external rotation moment was larger in the elite athlete during this phase compared to the sub-elites while the hip internal rotation moment was larger in the sub-elites compared the elite athlete (Figure 1).

Table 1: Kinematic profile of the pelvis, thorax, right shoulder, right wrist, stick, and maximum left hip kinetic comparison of successful shots between the elite and sub-elites athletes.

	Ball contact to release ROM (°)	Angular velocity (°/sec) at ball release				Max linear velocity (m/s) at ball release	Max left hip moment (Nm/kg)		
Athlete	Pelvis	Pelvic rotation	Thorax rotation	Right shoulder flexion	Right wrist flexion	Stick	Extensor	Adductor	Internal rotation
Elite	135.45 (5.61)	327.38 (56.38)	402.68 (141.13)	927.57 (111.39)	1069.15 (44.62)	20.15 (0.53)	3.61 (0.97)	2.41 (0.29)	-1.45 (0.24)
Sub-Elites	110.68* (9.39)	277.16 (69.85)	305.01 (129.17)	486.46* (200.48)	904.03 (199.40)	17.87* (0.66)	4.32 (0.98)	2.07 (0.71)	-2.14 (0.59)

Note. Significant difference at the $p < 0.05$ level. Mean data are presented along with the associated standard deviations in brackets.

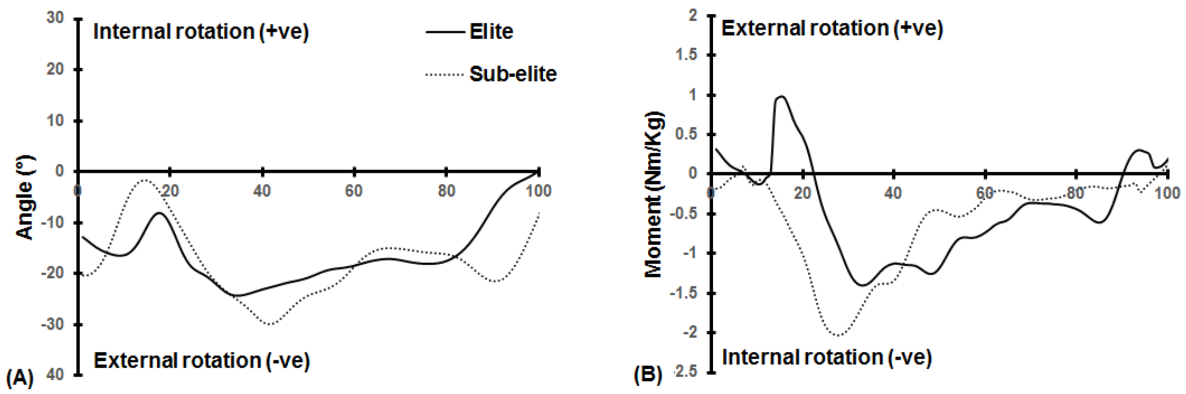

Figure 1: A representative trial comparison of the left hip internal/external rotation angle (A) and left hip internal and external rotation moment (B) between the elite (solid line) and one sub-elite (dotted line) athlete. On the x-axis, the trial denotes the start of left foot contact at 0 to left foot off at 100 (on the force plate).

DISCUSSION & CONCLUSION: The aim of this study was to investigate the kinematic and kinetics involved in the execution of the drag phase motion between a world class elite athlete and a group of sub-elite field hockey athletes. As hypothesised, the angular velocities from proximal-to-distal segments were larger in the elite athlete as compared to the sub-elite athletes. The angular velocity from the segments of all the participants in this study were similar to the study by Ibrahim et al. (2017) with the primary contribution beginning from the pelvis through to the trunk and finally the wrist before momentum is transferred to the stick. However, Ibrahim et al. (2017) proposed that the shoulder did not play a significant contribution to the kinematic sequencing of angular velocity though our results found that there is a significant difference in right shoulder flexion angular velocity between the elite compared to the sub-elites which could have resulted in a larger end point stick velocity (Table 1). This finding supports previous theories (Barlett 2007) which highlighted that the kinetic energy of each segment is transferred to the adjacent segment following the proximal-to-distal flow and that the elite athlete may have an improved or more efficient technique of sequencing the kinematic flow. The reduced angular velocities in the sub-elite athletes particularly at the shoulder, may be attributed to a decreased in overall strength at each segment of the kinematic flow (Barlett 2007; Ibrahim et al. 2017). The reduction in maximum stick velocity at ball release can also be attributed to the decrease in pelvis ROM of the sub-elite athletes (Table1). The elite athlete had more ROM at the pelvis which indicated that the athlete maximised the range in which he had to generate the torque possibly through the use of the stretch-shorten cycle (Turner & Jeffreys 2010). The increased ROM at the pelvis of the elite athlete could also be a result of a strategy employed to increase the separation between the pelvis and the thorax just before ball contact in an effort to increase the kinetic flow of energy from the pelvis to the thorax which is indicative of an improved proximal-to-distal kinematic sequencing (Ibrahim et al. 2017). In addition to the kinematics, it is noteworthy to detail the descriptive difference in left hip rotation during foot contact on the force plate between the elite and sub-elite athletes (Table 1 and Figure 1). The increased in internal rotation moment of the sub-elite athletes while the hip was externally rotating indicates an increased eccentric effort in the first 20% of foot contact compared to the elite athlete (Figure 1). This increased in eccentric work in the sub-elite athletes may be indicative of a weakness in the hip internal rotators which in turn may predispose the athletes to a higher risk of injury (Malloy et al. 2017). Ng et al. (2018) reported that due to the high degree of hip flexion combined with rotation while performing the drag flick, it places drag flickers at an increased risk of hip injuries. Although the sample size of this study was small, the results; specifically reduced ROM at the pelvis, reduced angular velocity from proximal-to-distal segments, and increased hip internal rotation moment of the sub-elites athletes compared to the elite athlete highlights the need for technique modification. More importantly, targeted strength training programs aimed at increasing the strength of the hip rotators may help with reducing the risk of injuries in drag flickers. Future research could look at electromyography measurements to profile the drag flick in greater detail together with the sequencing of kinematic flow from proximal-to-distal to shed light in the difference in control between elite and sub-elites field hockey athletes. In summary, the results of this study provides evidence for improvements in terms on technique modification and strength training for sub-elite drag flickers in field hockey to reduce their risk of injuries.

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