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Research Article

Swing Mechanics of the Offside Forehand in Professional Female Polo Athletes

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Abstract

Equestrian polo has experienced a 44% increase in participation over the last several years; however, there are a lack of data available describing this motion. In order to develop and implement training programs for youth athletes, there is a need to establish normative data for common polo swings, such as the offside forehand shot. The purpose of this study was to [1] describe trunk (flexion, lateral flexion, rotation) and upper extremity (shoulder horizontal abduction, elevation; elbow flexion) kinematics, and segmental speeds (humerus, forearm, hand) while performing the offside forehand polo swing in professional female polo athletes; and [2] examine the relationship of the kinematics variables and participant demographics with hand speed at the event of ball contact. Ten female professional polo players (33.0 ± 10.4 yrs.; 107.4 ± 22.1 cm; 66.9 ± 9.3 kg; 11.5 ± 8.1 yrs. of experience) participated. Kinematic data were collected at 100 Hz using an electromagnetic tracking system synced with The MotionMonitor™. Each participant performed three trials of the offside forehand swing. All swings were analyzed across three swing events (take away (TA), top of backswing (TOB), ball contact (BC)). Pearson product-moment correlations revealed significant relationships between hand speed and height ($R = 0.690$, $p = 0.027$); elbow flexion at TA ($R = -0.718$, $p = 0.019$), at TOB ($R = -0.635$, $p = 0.049$), and at BC ($R = -0.875$, $p = 0.001$). The kinematics observed suggests optimal energy transfer along the kinetic chain. The relationships imply that the more extended the elbow is throughout the course of the swing, the faster the hand will move thus propelling the mallet faster for ball contact.

Keywords: Equestrian Polo; Polo Development; Youth Polo Development

Introduction

Equestrian polo is a popular sport that is continuing to gain visibility and participation. In 2017, the United States Polo Association (USPA) reported a 44% increase in participation since 2008 [2]. Additionally in 2017, there were 341 polo athletes competing at the intercollegiate level and 266 youth athletes competing nationally [3]. Establishing fundamental programs for athlete development is imperative as participation increases at the younger levels and prominence of polo increases. With the insurgence of popularity of the sport of polo, the lack of data available describing swing mechanics is surprising and is an area that needs to be developed. Understanding the polo swing is a crucial step to creating effective youth training programs.

The polo swing can be described as a 360° motion of the upper extremity. To the authors' knowledge, there is only one study that describes polo swing mechanics, and this study focuses on male participants. This study reported that the greater the arm and mallet is away from the body, the greater the forces exerted on the elbow [4]. For the body to have efficiency during dynamic tasks, it must work in a coordinated fashion. This coordination is achieved by the body acting as a series of interdependent links known as the kinetic chain [5] Thus, the offside forehand polo swing must generate energy from the lower extremity and transfer it to the upper extremity for efficient output at the hand and on to the mallet for ball contact.

With the insurgence of polo participation, understanding normative data regarding the offside forehand polo swing is paramount for proper instruction, optimal performance, as well as injury prevention. No published study has examined trunk and upper extremity kinematics of the offside forehand polo swing; additionally, there are no known available polo swing data regarding females. Thus, it was the purpose of this study to (1) describe trunk (flexion, lateral flexion, rotation) and upper extremity (shoulder horizontal abduction, elevation; elbow flexion) kinematics, and segmental speeds (humerus, forearm, hand) while performing the offside forehand polo swing in professional female polo athletes; and (2) examine the relationship of the kinematics variables along with participant demographics with hand speed at the event of ball contact.

Methods

Experimental Approach to the Problem

A cross-sectional study with a convenience sample was implemented to obtain kinematic data of the offside forehand polo swing among female polo athletes. All testing was performed in a controlled laboratory setting on a stationary wooden horse, which is commonly used during teaching and training [1]. Each participant used their personal polo gear: helmet, boots, and mallet. Individual equipment was used in attempt to reduce variability caused from adaption of unfamiliar equipment.

Participants

Ten female professional polo players (33.0 ± 10.4 yrs.; 107.4 ± 22.1 cm; 66.9 ± 9.3 kg; 11.5 ± 8.1 yrs. of experience) with an average goal handicap of 1.5, were recruited to participate. Participants reported for testing prior to any polo or vigorous physical activity on that day. Selection criteria included being medically cleared to participate in polo activities as well as having no previous lower or upper extremity injuries within the past six months. The University Institutional Review Board approved all testing protocols. Prior to data collection, all testing procedures were explained to each participant, and written consent was obtained.

Procedures

Kinematic data were collected at 100 Hz using an electromagnetic tracking system (trakSTAR™, Ascension Technologies, Inc., Burlington, VT, USA) synced with The MotionMonitor™ (Innovative Sports Training, Chicago, IL., USA). Intra-rater reliability of digitization was determined during a pilot study of 9 participants. The investigator reported an intra-rater reliability of an ICC (3, k) of 0.75 to 0.93 for all digitization measurements. Nine electromagnetic sensors were affixed to the skin at the following locations: (1) posterior aspect of the trunk at the first thoracic vertebrae (T1) spinous process; (2) posterior aspect of the pelvis at the first sacral vertebrae (S1); (3) flat, broad portion of the acromion on the right scapula; (5,6) lateral aspect of the upper arm (bilaterally); (4,7) posterior aspect of the forearm (bilaterally), centered between the radial and ulnar styloid processes; (8,9) and the lateral aspect of the thigh (bilaterally), centered between the greater trochanter and the lateral condyle of the knee [4,7,10]. A tenth, moveable sensor was attached to a plastic stylus for the digitization of bony landmarks [8,9,11,12]. In order to ensure accurate identification and palpation of bony landmarks, the participant stood in anatomical neutral throughout the digitization process.

Sensor position and orientation raw data were transformed to locally based coordinate systems for each of the representative body segments. The world axis was defined as the positive y-axis in vertical direction; positive x-axis anterior to the y-axis and in the direction of movement; and positive z-axis orthogonal to x and to the right of y. Position and orientation of the body segments were obtained using Euler angle sequences that were consistent with the International Society of Biomechanics standards and joint conventions [11]. More specifically, ZX'Y" sequence was used to describe trunk motion and YX'Y" sequence was used to describe shoulder motion. All raw data were independently filtered along each global axis using a 4th order Butterworth filter with a cutoff frequency of 13.4 Hz [9,10,13].

Participants were allotted an unlimited amount of time to warm-up to allow for acclimation to all testing procedures following the digitization (average warm-up time: 3 min). The warm-up was not standardized because the investigators wanted each participant to feel sufficiently warm and capable of executing maximum effort swings without risking injury. As players prefer to strike the ball in different positions in relation to the horse, participants were asked to position the ball where they felt most comfortable striking to reduce need for adaptation. Each participant executed three maximum effort offside forehand swings. Successful trial criteria included (1) ball contact resulting in a straight ball flight and (2) verbal approval by the participant as a good swing. Participant approval was required because the offside forehand polo swing varies from player to player, and the "feel" components of striking an object is essential to a successful performance outcome in striking [4,14].

Statistical Analysis

Kinematic data were averaged across the three trials of the offside forehand polo swing. The offside forehand polo swing was divided into three swing events: (1) take away (TA), (2) top of back swing or apex of swing (TOB), and (3) Ball Contact (BC) (Figure 1).

Figure 1: Swing Events of the Polo Offside Forehand.

All data were processed using a customized MATLAB (MATLAB R2010a, MathWorks, Natick, MA, USA) script. Statistical analyses were performed using IBM SPSS Statistics 21 software (IBM Corp., Armonk, NY) for normally distributed data with an alpha level set a *priori* at $\alpha = 0.05$. Prior to analysis, Sharpio-Wilks tests of Normality were run and results revealed approximate normal distributions for all variables. Pearson's Product-Moment Correlations were run to examine the relationship between hand speed at BC with demographics (age, height, weight, and years of experience) and kinematic variables. Hand speed at BC was chosen because this is the most distal segment and would most closely reflect the speed the mallet is moving. Relationships were examined on a scatter plot and determined to be linear prior to analysis.

Results

Means and standard deviations (means+s) for the kinematic variables (Table 1), and segmental speeds are presented (Figure 2).

Table 1: Kinematic variables means and standard deviations at the three swing events.

Kinematic Variable (°)	TA	TOB	BC
Trunk Flexion	20±12	24±28	30±12
Trunk Lateral Flexion	22±22	44±22	52±14
Trunk Rotation	18±24	64±28	16±16
Shoulder Horizontal Abduction	48±34	70±34	56±30
Shoulder Elevation	48±20	90±26	60±18
Elbow Flexion	94±26	20±10	12±10
TA = Take Away; TOB = Top of Backswing; BC = Ball Contact			

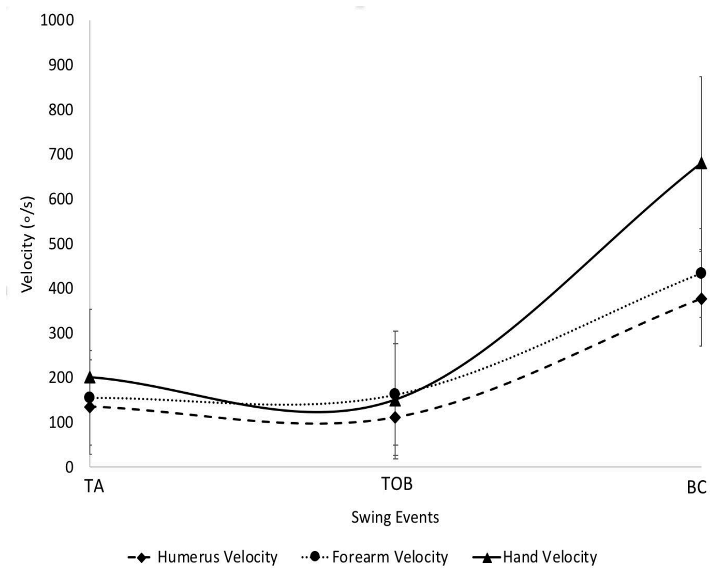

Figure 2: Segmental Speeds.

Examining the relationship between hand speed at BC and participant demographics as well as kinematics revealed significance. Correlations revealed significant relationships between hand speed and height ($R = 0.690$, $p = 0.027$); elbow flexion at TA ($R = -0.718$, $p = 0.019$), at TOB ($R = -0.635$, $p = 0.049$), and at BC ($R = -0.875$, $p = 0.001$) (Figures 3-6).

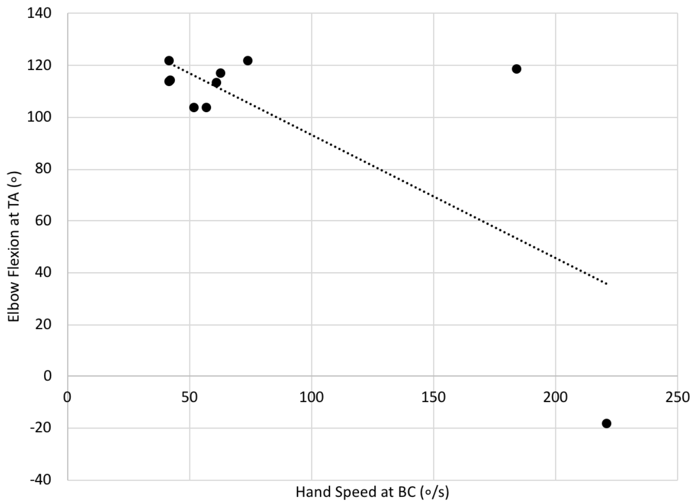

Figure 3: Correlation between hand speed at BC and elbow flexion at TA.

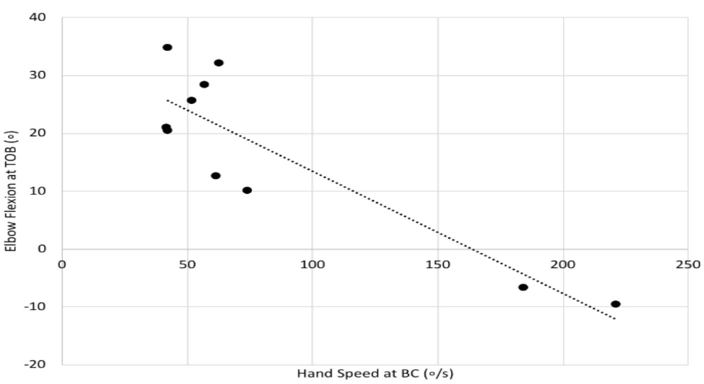

Figure 4: Correlation between hand speed at BC and elbow flexion at TOB.

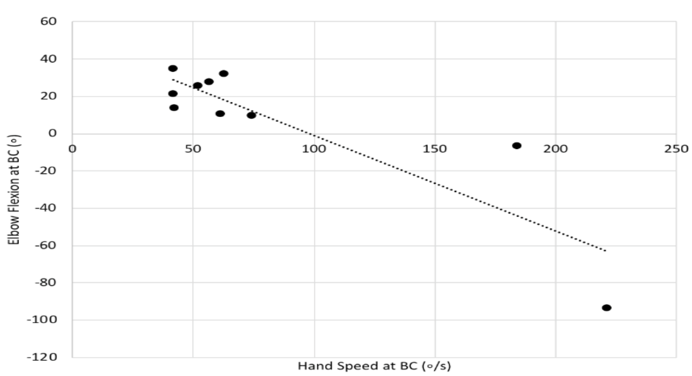

Figure 5: Correlation between hand speed at BC and elbow flexion at BC.

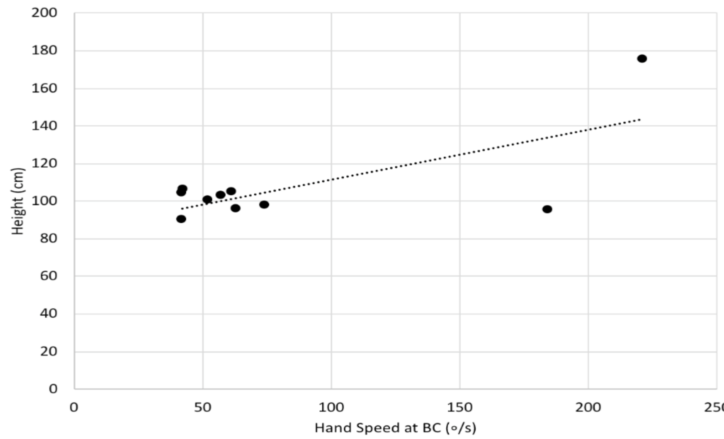

Figure 6: Correlation between hand speed at BC and elbow flexion and height.

Discussion

The purpose of this study was to describe trunk (flexion, lateral flexion, rotation) and upper extremity (shoulder horizontal abduction, elevation; elbow flexion) kinematics, and segmental speeds (humerus, forearm, hand) while performing the offside forehand polo swing in professional female polo athletes. Additionally, we examined the relationship of hand speed at BC and the aforementioned kinematics as well as participant demographics. The female polo athletes in the current study displayed a gradual increase in trunk forward flexion and lateral flexion (to the ball side) as they progressed through the swing phases of TA, TOB, and BC. Previous studies have found that energy is transferred most efficient when the trunk moves from a relatively extended to a relatively flexed position, and when the trunk moves towards the ball side throughout the movement [15]. The athletes in this study displayed these movement patterns, suggesting an efficient transfer of energy. Their trunk rotation was not as uniform in movement progression throughout the swing. The athletes exhibited a more neutral forward, square to the target, trunk position at TA and BC; in contrast, at TOB they displayed 64° of trunk rotation to ball side.

When examining the upper extremity kinematics of the shoulder and elbow, the athletes displayed their greatest shoulder abduction at the TOB. Elbow flexion was greatest at the event of TA and then progressively extended at the TOB and was almost fully extend at the initiation of BC. The shoulder horizontal abduction of 70° is less than the 120° shoulder horizontal abduction previously reported for male professional polo players [4]. However, though it is hard to make inferences between the two studies, Oliver et al., 2018 [4]. found that greater shoulder horizontal abduction was associated with greater elbow forces throughout the swing. This finding resulted in the authors eliciting that greater shoulder horizontal abduction during the countermovement phase (TA to

TOB) and at the event of TOB could predispose elbow injury due to the excessive forces produced [4]. Because the athletes in this study displayed relatively low values of shoulder abduction, this leads the authors to believe they are at lower risk for elbow injury. Investigation into the hand speed relationships is needed because in polo the main objective is to strike the ball with the mallet in attempt to propel the ball down the field to score a goal. This can be accomplished by striking the ball with the greatest mallet speed. Based on the summation of speed principle, the hand should be the fastest moving segment if the end goal is for maximum mallet speed at BC [6]. In agreement with the summation of speed principle, the current study revealed that at BC then hand had the greatest segmental speed. Additionally, it was found that those athletes in the current study who were taller and those who positioned their elbow in a more extended position throughout the swing were able to generate greater hand speed. These findings suggest an extended elbow is desired to generate more mallet speed and can be implementing in training tactics for youth athletes. The relationship pertaining to height and hand speed makes sense when comparing to a circular motion. In order for the entire arm to move at the same angular speed, the further away from the pivot a point is (i.e. the shoulder joint) the higher the linear speed must be to generate movement. Taller athletes tend to have longer arms, and therefore must have higher linear speeds at the hand and mallet.

Examination of trunk and upper extremity kinematics during the offside forehand polo swing of professional females is necessitated when organizations like the USPA put conscientious effort into youth polo development. Unfortunately, the authors are unable to compare the swing mechanics presented in the current study other professional polo athletes because of the paucity of data available in polo swing mechanics. Thus, this presentation is needed in attempt to establish normative data of the offside forehand polo swing. Limitations of this study include a small participation pool. However, the individuals in this study were from diverse regions and ages. The authors recommend this study be repeated amongst larger populations of both male and female polo athletes to further confirm findings presented.

Conclusion

The trunk and upper extremity kinematics in this study suggest that this particular group of athletes move in an efficient manner. There is a relationship between hand speed at BC with elbow flexion and height. This suggests that the more extended the elbow throughout the swing, the faster the hand will move, and thus the mallet. This relationship is analogous with increasing height. The authors recommend that further research be done to confirm findings of this study and continue to quantify movements in polo.

Acknowledgement

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