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Horizontal Shoulder Abduction and Elbow Kinetics in the Offside Forehand Polo Swing

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ABSTRACT

This study was conducted to examine the relationship between shoulder horizontal abduction and elbow kinetics (anterior/posterior, compression/distraction, and valgus/varus) during the offside forehand polo swing. We hypothesized those polo players who exhibited greater shoulder horizontal abduction during the offside forehand would also exhibit greater forces about the elbow. Seventeen male professional polo players (35.8 ± 11.1 years; 81.0 ± 9.2 kg; 116.0 ± 17.1 cm) were recruited to participate. All kinematic data were recorded with an electromagnetic tracking system synced with The MotionMonitor®. Each participant performed three maximum effort offside forehand swings, and each trial was analyzed at three swing events: 1) take away, 2) top of back swing, and 3) ball contact, and two phases: 1) counter movement phase (from the event of take away to top of back swing); and, 2) acceleration phase (from top of back swing to ball contact). Results revealed an offside forehand shot with greater shoulder horizontal abduction exhibited greater elbow kinetics, thus supporting our hypothesis. These findings suggest that keeping the polo mallet in an acceptable swing path would minimize elbow kinetics and perhaps reduce injury. Future studies should gather offside forehand kinetic data from players on a moving horse and examine the relationship between shoulder horizontal abduction with elbow and shoulder kinetics.

Keywords: Elbow valgus, Equestrian polo, Swing analysis, Swing mechanics, Upper extremity injury.

INTRODUCTION

Equestrian polo is one of the world's oldest sports and is increasing in popularity in the United States. In 2008, the United States Polo Association (USPA) reported 3,774 registered playing members, but in 2016, membership increased to 5,451 registered playing members. In 2017, there were 97 intercollegiate polo teams consisting of 341 players competing in separate divisions across four regions. At the youth level, there were 93 teams consisting of 266 players competing in the National Youth Tournament Series. With the increasing participation rates, specifically in youth development programs, the understanding of the polo swing is paramount. Defining the mechanics of the polo swing, executed by elite polo athletes, will assist in polo instruction amongst youth athletes.

Polo is a team sport played on a horse with the objective of the game being to score more goals than the opposing team. Goals are scored when an athlete hits a small, white ball into the opposing team's goal using a long mallet. The sport of polo requires the athlete to be stable on a horse, swing a mallet above head, and strike a moving ball on the ground while the horse is moving at a fast pace. The mallet length typically ranges from 50 inches (1.27 m) to 53 inches (1.34 m), depending on the height of the horse. The game is usually played outdoors on a field 300 feet (91.44 m) in length and 160 feet (48.77 m) in width. Teams consist of only four players who are required to play the entire game. A game lasts approximately 2 h and is divided into six time periods called chukkas.

The offside forehand is the most common swing in polo, which requires the mallet to be raised above the head and swung down as a weighted pendulum for ball contact. The long mallet increases the lever arm of the swing but when preformed improperly, especially repeatedly, can lead to injury. Previous polo injuries have been concentrated in the upper extremities and can be partially attributed to overuse. In similar overhead motions, such as the windmill softball pitch, it has been found that shoulder horizontal abduction is related to increased forces and thus injury susceptibility at the shoulder and elbow however, to the authors' knowledge there are no data available examining the kinematics and kinetics of the offside forehand polo swing. When examining the game duration of 2h, with only four players per team, the number of swings performed per player is immense. Understanding proper swing mechanics is crucial when considering the repetitive swings performed during a single game. Additionally, with the increased participation in polo, it is crucial to understand proper swing mechanics and the forces about the upper extremity. Therefore, the purpose of this study was to examine shoulder horizontal abduction and elbow kinetics (anterior/ posterior, compression/distraction, and valgus/varus) during the offside forehand polo swing. It was hypothesized that polo players who exhibited greater shoulder horizontal abduction during the offside forehand would also exhibit greater forces about the elbow.

MATERIALS AND METHODS

Experimental approach to the problem

In order to determine the relationship of shoulder horizontal abduction with elbow kinetics, a cross-sectional study with a convenience sample was conducted. Testing was performed in a controlled laboratory setting on a stationary wooden horse, which is commonly used during teaching and training. Participants used their personal polo playing gear: helmet, boots and mallet. Individual equipment was used in attempt to reduce variability caused from adaption of unfamiliar equipment.

Participants

Seventeen male professional polo players (35.8 ± 11.1 years; 81.0 ± 9.2 kg; 116.0 ± 17.1 cm) were recruited to participate. Player handicaps ranged from 1 goal to 6 goals, with an average handicap of 4 goals. 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

Data were collected at 100 Hz using an electromagnetic tracking system (trakSTARTM, Ascension Technologies, Inc., Burlington, VT, USA) synced with The MotionMonitor^{TM} (Innovative Sports Training, Chicago, IL, USA). Nine electromagnetic sensors were affixed to the skin at the following locations (Figure 1): posterior aspect of the trunk at the first thoracic vertebrae (T1) spinous process [1]; posterior aspect of the pelvis at the first sacral vertebrae (S1) [2]; flat, broad portion of the acromion on the right scapula [3]; lateral aspect of the upper arm (bilaterally) [4,5]; posterior aspect of the forearm (bilaterally), centered between the radial and ulnar styloid processes [6,7]; and, the lateral aspect of the thigh (bilaterally) [8,9], centered between the greater trochanter and the lateral condyle of the knee [10-14]. A tenth, moveable sensor was attached to a plastic stylus for the digitization of bony landmarks [12,13,21,22]. In order to ensure accurate identification and palpation of bony landmarks, the participant stood in anatomical neutral throughout the digitization process. Using the digitized joint centers for the ankles, knees, hips, shoulders, T12-L1 and C7-T1, a link segment model was developed.

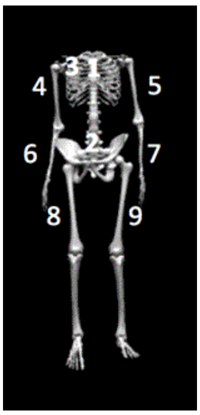

Figure 1: Sensor placement

Joint centres were determined by digitizing the medial and lateral aspect of a joint then calculating the midpoint between those two points [12,13,21]. The knee joints were defined as the midpoint between the digitized medial and lateral malleoli and medial and lateral femoral condyles, respectively, whereas the spinal column was defined as the digitized space between C7-T1 and T12-L1. A rotation method, validated as capable of providing accurate positional data, [15] was utilized to estimate the joint centres of the shoulder and hips. The shoulder joint centre was calculated from the rotation of the homers relative to the scapula while the hip joint centres were calculated from the rotation of the femur relative to the pelvis. The rotation method consisted of the investigator stabilizing the joint then passively moving the limb into six different positions in a small, circular pattern [16].

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 the vertical direction [17-20]; 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 [21]. More specifically, ZX'Y" sequence was used to describe pelvis and 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 cut off frequency of 13.4 Hz [13,14,19].

Following sensor attachment and digitization, participants were allotted an unlimited amount of time to warm-up (average warm up time: 5 min) for acclimation to all testing procedures. 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 it is known that the "feel" components of striking an object are essential to a successful performance outcome in striking [20].

Statistical analysis

Kinematic and kinetic data were averaged across the three trials of the offside forehand polo swing. The offside forehand polo swing was analysed at three swing events: 1) take away, 2) top of back swing, and 3) ball contact. In addition, the swing was divided into two phases: 1) counter movement phase (from the event of take away to top of back swing); and, 2) acceleration phase (from top of back swing to ball contact) (Figure 2). Elbow kinetics as well as maximum shoulder horizontal abduction were analysed across these two phases. All data were processed using a customized MATLAB (MATLAB R2010a, Math Works, Natick, MA, USA) script. Statistical analyses were performed using IBM SPSS Statistics 21 software (IBM Corp, Armonk, NY) for both normally and non-normally distributed data with an alpha level set *a priori* at α=0.05.

Prior to analysis, Sharpio-Wilk tests of Normality were run, and data were determined to be normally distributed. Pearson rank correlations were used to analyze the relationship between elbow kinetics and shoulder horizontal abduction.

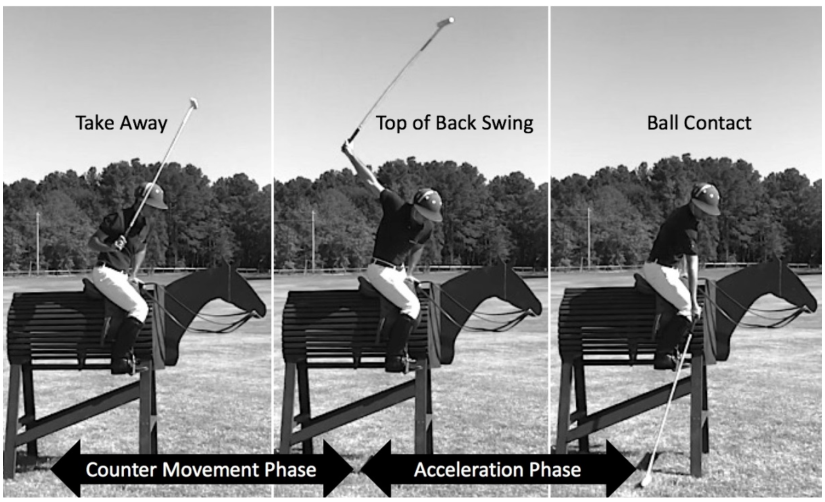

Figure 2: Events and phases of the offside forehand polo swing

RESULTS AND DISCUSSION

Means and standard deviations for all force variables during both phases of the swing are shown in Table 1. Means and standard deviations for the values of shoulder horizontal abduction are shown in Table 2. Pearson rank correlation revealed a significant positive relationship between shoulder horizontal abduction during the counter movement phase and elbow anterior/posterior force during the acceleration phase (R=0.500, p=0.049). Thus, 25% of the variance of elbow anterior/posterior force being accounted for by its linear relationship with shoulder horizontal abduction during the counter movement phase of the polo swing (r^2=0.250). A significant positive relationship was also found between horizontal shoulder abduction at the top of the backswing and elbow anterior/posterior force during the acceleration phase (R=0.570, p=0.021). 33% of the variance of elbow anterior/posterior force during the acceleration phase being accounted for by its linear relationship with horizontal shoulder abduction at the top of the backswing (r^2=0.330). A significant negative relationship was found between shoulder horizontal abduction during the counter movement phase and elbow distraction/compression forces during the acceleration phase (R=-0.570, p=0.022). 33% of variance in elbow distraction/compression forces during the acceleration phase being accounted for by its linear relationship with shoulder horizontal abduction during the counter movement phase (r^2=0.330). Additionally, another significant negative relationship was found in the acceleration phase between shoulder horizontal abduction and elbow valgus/varus force (R=-0.500, p=0.049). 25% of the variance of elbow valgus/varus force being accounted for by its linear relationship with shoulder horizontal abduction during the acceleration phase (r^2=0.250). Pearson correlation coefficients can be found in Table 3.

Elbow Force	Counter Movement Phase (weight-normalized)	Acceleration Phase (weight-normalized)
Max	0.056 ± 0.012	0.190 ± 0.035
Valgus/Varus	0.017 ± 0.014	0.053 ± 0.049
Distraction/Compression	0.039 ± 0.009	0.159 ± 0.033
Anterior/Posterior	0.033 ± 0.014	0.063 ± 0.049

Table 1: The means and standard deviations of the forces observed on each joint during each phase of the swing are displayed.

	Shoulder Horizontal Abduction (∘)
Counter Movement Phase	130 ± 22
Acceleration Phase	48 ± 24
Take Away	80 ± 38
Top of Backswing	120 ± 21
Ball Contact	60 ± 24

Table 2: The means and standard deviations of shoulder horizontal abduction at each event and the average shoulder horizontal abduction over each phase is displayed.

The purpose of this study was to determine the relationship between shoulder horizontal abduction and elbow (anterior/posterior, compression/distraction, and valgus/varus) kinetics during the offside forehand polo swing. The findings from this study support our hypothesis of an offside forehand shot with greater shoulder horizontal abduction exhibiting greater elbow kinetics.

Greater shoulder horizontal abduction during the counter movement phase and at the top of the backswing of the offside forehand correlates with greater elbow anterior/posterior force during the acceleration phase of an offside forehand. As the mallet was taken away to be positioned at the top of backswing, and the further away from the body the mallet was, the greater the anterior forces were on the elbow. This maneuver of taking the mallet away with more shoulder abduction is similar to the coined 'tennis takeaway' [6]. In similar overhead dynamic motions such as the windmill softball pitch, it has been found that greater shoulder horizontal abduction during the 360° overhead dynamic movement corresponds to greater anterior/posterior forces on the elbow [7]. The current study agrees with previous findings regarding a 360° dynamic movement similar to the polo swing since greater shoulder horizontal abduction is associated with greater anterior/posterior elbow forces. To the author's knowledge, there are no data examining the effects of shoulder horizontal abduction and upper extremity kinetics during the offside forehand polo swing. Thus, extraction of data from the windmill softball pitch allows for the most resemblance and comparison of the 360° dynamic overhead movement of the polo swing [10-15].

	SHOULDER HORIZONTAL ABDUCTION				
	Counter Movement Phase	Acceleration Phase	Take Away	Top of Backswing	Ball Contact
Counter Movement Phase					
Valgus/Varus	0.474	-0.075	-0.091	0.465	0.017
Distraction/Compression	-0.096	-0.201	-0.434	0.041	-0.143
Anterior/Posterior	-0.107	-0.077	0.080	0.051	-0.134
Acceleration Phase					
Valgus/Varus	-0.214	-0.500*	-0.145	-0.138	-0.462
Distraction/Compression	-0.567*	-0.076	0.247	-0.356	-0.252
Anterior/Posterior	0.499*	0.170	0.451	0.571*	0.199

Note: * indicates significance of $p \leq 0.050$ (2-tailed)

Table 3: Pearson's product correlation of shoulder horizontal abduction (∘) and elbow kinetics (weight-normalized) during the counter movement phase and the acceleration phase. (n = 16).

The negative correlation of shoulder horizontal abduction and elbow distraction/compression force reveals that the greater the shoulder horizontal abduction during the countermovement phase, the greater the elbow distraction forces. More specifically, the further the mallet is taken away from the body to position the athlete at the top of backswing, the greater the distraction forces are on the elbow during the acceleration phase. A previous study found that when elbow distraction forces dropped at approximately 50% of the throw, shoulder horizontal abduction exhibited a proportional drop at approximately 100% of the throw [7]. From a performance perspective, these current data support the notion of maintaining efficient mechanics during the counter movement phase of the polo swing [6,18-20].

The correlation of shoulder horizontal abduction and elbow valgus/varus during the acceleration phase exposes the notion of the importance of keeping the mallet in the swing plane, or close to the body. The swing plane has been described as the parallel plane to the horse's body. The USPA has emphasized the movement of the mallet in the swing plane as the movement progresses from top of backswing through ball contact [6], however until now, no data have been able to support this notion. The current data suggest that the further away from the body or the greater the deviation the mallet is from the swing plane during the acceleration phase, the greater the valgus force exerted on the elbow. Additionally, these findings are in agreement with previous data examining the windmill softball pitch in that changes in shoulder horizontal abduction almost instantaneously resulted in an equivalent change in elbow valgus forces [7]. Thus supporting the notion of maintaining the mallet within the swing plan for proper swing instruction.

Examining the mechanics, specifically shoulder horizontal abduction, of the offside forehand polo swing in professional polo players is imperative for understanding the fundamentals of proper swing instruction and performance. With the increased participation rates as well as the insurgence of youth polo development, establishing proper mechanics as well as understanding the injurious effects of improper mechanics is vital. The finding of greater elbow valgus forces when the mallet is outside the swing plane has injury implications [2]. As elbow valgus forces lead to tension on the medial side and compression of the lateral side [18]. Though data are sparse regarding polo, there has been reports of overuse injury in polo athletes with improper swing mechanics with indication of faulty mechanics as the mechanism of injury [8,9]. Elbow valgus force injuries are commonly seen in throwing sports and are typically the result of faulty mechanics, constant repetitive overuse and fatigue [1,11,18]. Specifically, the onset of trunk rotation, maximum shoulder external rotation, and elbow flexion have been linked to elbow injury [1,11]. Like throwing, the offside forehand shot for polo is a movement that incorporates the entire body to work as a kinetic chain. It is essential for the body to be efficient as possible to limit elbow valgus kinetics and thus keep injury possibility to a minimum. With the length and the game and amount of swings per player, studies of this nature should be replicated for polo [22].

Limitations of this study include a small sample size. In addition, all data were recorded on a wooden, stationary horse. Although athletes regularly train on stationary horses like the one used in this study, a more accurate quantification of the kinetics and kinematics would occur if data were recorded while the athlete was on a moving horse.

CONCLUSION

The findings of this study show that a relationship exists between shoulder horizontal abduction and elbow kinetics for the offside forehand polo swing. Specifically, increased shoulder horizontal abduction during the offside forehand is associated with increased anterior, distraction, and valgus force on the elbow. In order to prevent injury, a polo player is advised to keep the mallet on the proper swing plane, or limit the shoulder horizontal abduction during the countermovement phase of the swing. Future research examining the offside polo swing and the relationship between shoulder horizontal abduction and should kinetics as well as trunk positioning is warranted. Establishing normative data from the most common polo swing, offside forehand, will further allow for future investigations into other commonly utilized swings such as the nearside forehand, offside backshot and nearside backshot should be examined in order to decrease injury and improve performance.

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