# TRUNK AND UPPER EXTREMITY KINEMATICS OF THE OFFSIDE FOREHAND POLO SWING IN PROFESSIONAL POLO ATHLETES

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The purpose of this study was to examine trunk (flexion, lateral flexion, rotation) and upper extremity (shoulder horizontal abduction, elevation, and elbow flexion) kinematics of the offside forehand polo swing between professional male and female polo athletes. Kinematic data were collected while participants performed the offside forehand polo swing on a stationary wooden horse. The polo swing was analyzed at three events: take away (TA), top of back swing (TOB) and ball contact (BC). Results revealed significant differences in trunk and upper extremity kinematics between the male and female professional polo athlete. Further investigation into these mechanical differences, along with the influence of live play and performance variables are necessitated to understand mechanics for the most powerful swing

**KEYWORDS:** equestrian polo, motion analysis, swing mechanics.

**INTRODUCTION:** One of the world's oldest sports is equestrian polo. Even though polo is widely recognized, it is fundamentally misunderstood (Young, 2016). The team sport of polo is one of the select sports that is not sex-segregated, with the exception of collegiate play. Additionally, polo is not segregated by age. Instead, each athlete is given a rating (handicap) that determines level of play. Each team consists of four polo athletes who play the entire game. A game is broken up into seven-minute periods called chukkers, and athletes change mounts (horses) after every chukker. A typical game is six to seven chukkers.

The most common and first taught swing in polo is the offside forehand, which can be described as a 360° motion of the upper extremity. The large range of motion is similar to what is displayed in the windmill softball pitch. Polo is not only an overhead sport; it is also a sport susceptible of constant repetitive overuse upper extremity movements. In similar overhead sports that perform constant repetitive movements, it has been found that shoulder horizontal abduction is related to increased forces and thus injury susceptibility at the shoulder and elbow. The only study to the authors' knowledge examining overuse injuries surveyed all members of the United States Polo Association (USPA) and found that the shoulder was the most injured site when examining overuse types of injury. From a survey of 531 USPA members, shoulder injuries were reported in 65% of the males and 32% of the females (Merlini, 2004). When examining the game duration, the nature of the dynamic overhead activity of swinging the mallet, and the stipulation of only four players per team, the number of swings performed per player is considerable. Understanding proper swing mechanics is crucial when considering the repetitive swings performed during a single game. Since the game does not separate athletes by sex however, anecdotally, it is believed that males display different mechanics than females during the polo swing, it was the purpose of this study to examine trunk (flexion, lateral flexion, rotation) and upper extremity (shoulder horizontal abduction, elevation; elbow flexion) kinematics of the offside forehand polo swing between professional male and female polo athletes. It was hypothesized that there would be no differences in kinematics between male and female athletes.

**METHODS:** Twenty-seven professional polo athletes volunteered to participate. Participants included ten female professional polo players (33.0 ± 10.4 yrs.; 1.69 ± 0.06 m; 66.9 ± 9.3 kg; 11.5 ± 8.1 yrs. of experience) and seventeen male professional players (35.8 ± 11.1 yrs.; 1.81 ± 0.06 m; 81.0 ± 9.2 kg; 15.7 ± 10.2 yrs. of experience). All participants were actively playing polo competitively, in good physical condition, and had no injuries within the last six months. The University's Institutional Review Board approved all testing protocols.

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). Thirteen electromagnetic sensors were attached in accordance with previously established methods (Oliver, 2018a; Oliver 2018b). Raw data regarding sensor position and orientation were transformed to locally based coordinate systems for each of the representative body segments. For the world axis, the y-axis represented the vertical direction. Anterior of the y-axis, in the direction of movement was the positive x-axis. Orthogonal to x and to the right of y was the positive z-axis. 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 (Wu, 2002; Wu, 2005). More specifically, ZX'Y" sequence was used to describe pelvis and trunk motion and YX'Y" sequence was used to describe shoulder motion. Data were time stamped through The MotionMonitor™ and passively synchronized using a data acquisition board.

Following sensor attachment and digitization, participants were allotted an unlimited amount of time to warm-up to allow for acclimation to the 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 optimal 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" component of striking an object is essential to a successful performance outcome in striking.

The swing was analyzed at three events: (1) take away (TA), (2) top of back swing or apex of swing (TOB), and (3) ball contact (BC). Figure 1 depicts the three swing events that were analyzed. 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, Shapiro-Wilks tests of Normality were run and results revealed approximate normal distributions for all variables. Kinematics data were averaged across three swing trials. Between group one-way ANOVAs were employed to examine the differences in kinematics between the male and female athletes.

Take Away (TA) Top of Backswing (TOB) Ball Contact (BC)

**Figure 1: Events of the offside forehand polo swing.**

**RESULTS:** Table 1 displays the means and standard deviations of each variable at all events for both males and females. The between group one-way ANOVAs revealed significant differences in trunk flexion at TA and TOB; trunk lateral flexion at TA and BC; trunk rotation at all events; shoulder horizontal abduction at TOB; shoulder elevation at TA and BC; and elbow flexion at TA.

**Table 1: Kinematic Variables (M ± SD) at Swing Events**

| Kinematic Variable (°) | Groups | TA | TOB | BC |
|---|---|---|---|---|
| Trunk Flexion | Male | 37 ± 20* | 44 ± 16* | 37 ± 13 |
| | Female | 14 ± 12* | 15 ± 15* | 32 ± 20 |
| Trunk Lateral Flexion | Male | 32 ± 11* | 50 ± 9 | 46 ± 8* |
| | Female | 45 ± 8* | 57 ± 8 | 23 ±9* |
| Trunk Rotation | Male | 113 ± 19* | 137 ± 41* | 73 ± 19* |
| | Female | 16 ± 19* | 19 ± 139* | 164 ± 18* |
| Shoulder Horizontal Abduction | Male | 38 ± 56 | 83 ± 54* | 22 ± 63 |
| | Female | 2 ± 54 | 19 ± 43* | 66 ± 45 |
| Shoulder Elevation | Male | 35 ± 13* | 62 ± 17* | 45 ± 12* |
| | Female | 54 ± 36* | 49 ± 41* | 5 ± 33* |
| Elbow Flexion | Male | 11 ± 91* | 9 ± 22 | 2 ± 16 |
| | Female | 101 ± 42* | 17 ± 15 | 7 ± 38 |

*indicates significance of $p \leq 0.050$. **Trunk Flexion**: (+) = forward flexion, (-) = extension; Trunk Rotation: 0° = facing forward, 90° = rotated to mallet side; Trunk Lateral Flexion: (+) = mallet side, (-) = non-mallet side; Shoulder Horizontal Abduction: 0° = forward flexion, 90° = abduction; Shoulder Elevation: 0° = no elevation, 180° = full elevation; Elbow Flexion: (+) = flexion, (-) = extension.

**DISCUSSION:** The purpose of this study was to examine and compare the offside forehand polo swing in male and female professional polo athletes. Since equestrian polo is not sex-segregated, the significant differences in swing kinematics were somewhat surprising. Male athletes exhibited greater trunk forward flexion at the events of TA and TOB, less lateral flexion to the ball side at TA, and greater lateral flexion to the ball side during BC. Upon further examination into the swing, it was evident that both sexes positioned their trunk and upper extremity in a power position for energy transfer. As it has been reported that energy is transferred most efficiently 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 (Tanaka, 2016). This finding is in agreement with previous data describing the sequencing of trunk rotation, and its role in injury risk in overhead movements (Oyama, 2014). In polo, motion of the pelvis is restricted due to the athlete sitting on a horse. Trunk rotation helps establish the pelvic/trunk separation seen as a vital part in other sporting movements (Fleisig, 2013; Myers, 2008; Oyama, 2014). Because of the importance of trunk rotation in sporting movements, it is surprising to see such differences in trunk rotation between sex for the offside forehand swing. The males utilized greater trunk rotation to the ball side which is possibly a mechanism of energy generation.

Examination of shoulder kinematics revealed differences in shoulder horizontal abduction only at TOB while differences in shoulder elevation were revealed throughout the entire swing. Previous studies have shown that forces about the elbow are lower when the arm is kept closer to the body (Oliver, 2018a). Because the males' arms were positioned further from the body, this suggests there are more forces acting on their elbow which may put them in a more injury prone position.

Kinematic differences in elbow flexion were only noted at TA, where the males exhibited a more extended elbow while the females were more flexed. Previous studies have found that an extended elbow is associated with increased hand speed at BC (Oliver, 2018b), which ultimately results in greater mallet and ball speeds.

Because both males and females train together in polo, the ultimate cause of these differences are unknown. Thus, further examination into these mechanical differences including trunk and pelvic stability, as well as performance measures such as ball velocity are warranted.

Limitations to this study include being in a laboratory on a stationary wooden horse versus on a field with an actual horse.

**CONCLUSION:** The findings from this study reveal that the male athletes' trunk position could possibly allow for optimal energy transfer to the upper extremity. The upper extremity differences could be a result of the trunk position since the body acts as a kinetic chain in a proximal to distal fashion. However, further research is needed for more definite conclusions to be made.

**REFERENCES:**

Fleisig, G.S., Hsu, W.K., Fortenbaugh, D. Cordover, A. Press, J.M. (2013). Trunk axial rotation in baseball pitching and batting. *Sports Biomechanics,* 12, 324-333.

Merlini, V.L. A case study of the equestrian sport of polo: An integrative approact to issues of structure, function, and interaction. University of Connecticut; 2004: 292

Meyers, J., Lephart, S., Tsai, Y.S., Sell, T. Smoliga, J. Jolly, J. (2008). The role of upper torso and pelvis rotation in driving performance during the golf swing. *Journal of Sports Sciences,* 26, 181-188.

Oliver, G.D., Keeley, D.W. (2010a). Gluteal muscle group activation and its relationship with pelvis and torso kinematics in high-school baseball pitchers. *Journal of Strength and Conditioning Research,* 24, 3015-3022.

Oliver, G.D., Keeley, D.W. (2010b). Pelvis and torso kinematics and their relationship to shoulder kinematics in high-school baseball pitchers. *Journal of Strength and Conditioning Research,* 24, 3241-3246.

Oliver, G.D., Barfield, J.W., Gilmer, G.G., Brittain, A.R., Washington, J.K. (2018a). Horizontal shoulder abduction and elbow kinetics in the offside forehand polo swing. *European Journal of Sports and Exercise Science*, 5, 53-58.

Oliver, G.D., Gilmer, G.G., Barfield, J.W., Brittain, A.R. (2018b). Swing mechanics of the offside forehand in professional female polo athletes. *Journal of Orthopedic Research and Therapy,* doi: 10.29011/2575-8241. 000080

Oyama, S., Yu, B., Blackburn, J.T., Pauda, D.A., Myers, J.B. (2014). Improper trunk rotation sequence is associated with increased maximal shoulder external rotation angle and shoulder joint force in high school baseball pitchers. *American Journal of Sports Medicine*, 42,2089-2094.

Tanaka, H. Hayashi, T., Inui, H. Ninomiva, H. Muto, T., et al. (2016). Influence of combinations of shoulder, elbow, and trunk orientation on elbow joint loads in youth baseball pitchers. *Orthopaedic Journal of Sports Medicine,* 4(7 suppl4): 2325967116S00204.

Wu, G., Siegler, S., Allard, P., Kirtley, C., Leardini, A., Rosenbaum, D., Whittle, M., D'Lima, D.D., Cristofolini, L., Witte, H., Schmid, O., Stokes, I. (2002). ISB recommendation on definitions of joint coordinate system of various joints for reporting of human joint motion-part I: ankle, hip, and spine. *Journal of Biomechanics,* 35, 543-548.

Wu, G., van der Helm, F.C.T., Veeger, H.E.J., Makhsous, M., Van Roy, P., Anglin, C., Nagels, J., Karduna, A.R., McQuade, K. Wang, X., Werner, F.W., Buchholz, B. (2005). ISB recommendation on definitions of joint coordinate systems of various joints for the reporting of human joint motion—Part II: shoulder, elbow, wrist and hand. *Journal of Biomechanics,* 38, 981-992.

Young G. Equestrian crash course: What you need to know about polo. In: Network H ed; 2016

**ACKNOWLEDGEMENTS:** The authors would like to thank the United States Polo Association LLC for their financial support of this study.