UPPER AND LOWER EXTREMITY MUSCLE FIRING PATTERNS DURING THE WINDMILL SOFTBALL PITCH

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The purpose of this study was to describe the activity of both the upper and lower extremity muscles during the windmill softball pitch. Seven female post-pubescent softball pitchers volunteered for the study. Pitchers were analyzed with surface electromyography, and motion analysis software. The muscle firing patterns were described during five phases of the windmill softball pitch.

KEY WORDS: sEMG, female, mechanics of pitching

INTRODUCTION: With millions of girls participating in high school and collegiate softball, there is limited research available. The baseball pitch has been investigated intensively, and continues to be investigated. Barrentine et al. (1998) observed similar torques in softball as that of baseball, and therefore with the risk of injuries in windmill softball pitching becoming as paramount as those in baseball, the mechanics of the motion of the pitch are imperative to understand (Maffet et al., 1997; Werner et al., 2005).

However, it is also known that the body is a kinetic link model, which describes the body as interdependent segments, thus contribution of the entire body during sport activities is essential (McMullen & Uhl, 2000). The proximal segments of the legs and trunk work sequentially in effort to accelerate the shoulder for optimal force production in upper extremity activities (Putnam, 1993). Furthermore, the large muscles of the hips and trunk help position the thoracic spine to accommodate appropriate motions of the scapula which allow for functional shoulder motion. Adequate firing of the gluteal muscle group is vital in proximal to distal sequencing in ballistic/dynamic movements such as the windmill softball pitch.

Previously the research has focused solely on the upper extremity muscle function with the windmill softball pitch. Maffet et al. (1997) examined the activation patterns of eight muscles of the upper extremity and Rojas et al. (2009) examined the biceps during the five phases of the windmill pitch. However, there is no study to date that examines both the upper and lower extremity muscle-firing patterns throughout the phases of the windmill softball pitch. Therefore, the purpose of this study was to examine and describe the muscle firing patterns of three upper extremity muscles (biceps, triceps, and rhomboids [scapular stabilizers]) and two lower extremity muscles (gluteus maximus and medius) during the five phases of the windmill softball pitch.

METHODS: Data Collection: Four collegiate and two high school female post pubescent softball pitchers (age 17.7 y $\pm$ 2.6; height 169 cm $\pm$ 5.4; mass 69.1 kg $\pm$ 5.4) consented to participate. Participants were recruited from the local high school and University. The study was granted Institutional Review Board approval. None of the participants had any previous or current musculoskeletal injury. Surface electromyography (sEMG) data were collected on three muscles of the throwing (dominant) arm, and stride leg (non-dominant leg) as per previously described protocols of Maffet et al. (1997) and Rojas et al. (2009). Surface EMG electrodes were placed on the muscle bellies of the biceps, triceps, rhomboids (scapular stabilizers), gluteus maximus and gluteus medius using Myopac Jr 10 channel amplifier (RUN Technologies Scientific Systems, Laguna Hills, CA).

To assure proper electrode placement, a certified athletic trainer (P.D.) performed manual muscle tests through maximum isometric voluntary contractions (MVIC) based on the work of Kendall et al. (1993). In addition, all sEMG data were performed by the certified athletic trainer (P.D.). Manual muscle tests were performed on each muscle three times for five seconds. The first and last second of each MVIC trails were removed from the data in attempt to obtain steady state results for each of the muscle groups. The manual muscle testing provided a base line reading for which all EMG data were based.

In addition to sEMG data, kinematic data were collected simultaneously in attempt to identify the different phases of the pitch. Kinematic data were collected using The Motion Monitor® system (Innovative Sports Training, Chicago IL) and throwing kinematics were calculated using the International Society of Biomechanics recommendations for reporting joint motion (Wu et al., 2005). Electromagnetic sensors were placed on the thorax, sacrum, dominant distal-forearm, right and left distal-humerus, and right and left mid-shank. Both sEMG and force plate data were collected at a rate of 1000Hz. Force plate, kinematic, and sEMG data were synchronized using The Motion Monitor®.

After unlimited time was allotted for the participants to warm-up based on their normal routine, each participant threw fastball windmill style deliveries using an official softball (30.48 cm. circumference, 170.1 g.) to a catcher behind the plate 12.2 m away. Unlimited warm-up was allowed to account for individual differences in throwing preparation that would be similar to the participant throwing in a game situation. Five trials were recorded after they were deemed a successful strike.

Data Analysis: After completion of the trials, positional kinematic data were filtered independently along the x, y, and z-axis using a 2nd order Butterworth filter (10 Hz) (Werner et al. 2005). The sEMG signals were preamplified (x 1200) near the electrodes and were band pass filtered between 10 and 500 Hz and sampled at a rate of 1000 Hz (Rojas et al., 2009). Surface EMG enveloped data were assessed through mean maximum sEMG reference values that were calculated for each muscle during each of the five phases of the pitch. The five phases were defined according to Maffet et al. (1997) and are illistrated in Figure 1. In the softball pitch there are typically six phases, however, this study focused on all activity prior to ball release and at ball release, excluding the follow-through phase. Five trials of sEMG data for each participant were analyzed to determine average peak amplitudes for all muscles during the first five phases of the pitch. Phase 1 was described as the windup or from the initial movement to the 6 o'clock position. Phase 2 was from the 6 o'clock position to the 3 o'clock position. Phase 3 was from 3 o'clock to 12 o'clock. Phase 4 was from 12 o'clock to 9 o'clock and Phase 5 was from 9 o'clock to ball release.

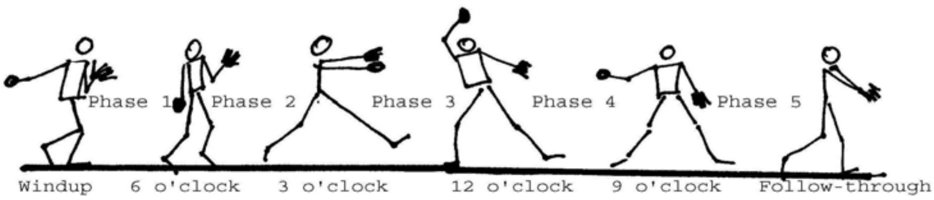

Figure 1: Windmill pitching phases.

RESULTS: The gluteus medius muscle had the greatest activity throughout the entire pitch. The gluteus maximus muscle and then the rhomboids (scapular stabilizers) followed with their activity. Results are graphically summarized in Figure 2.

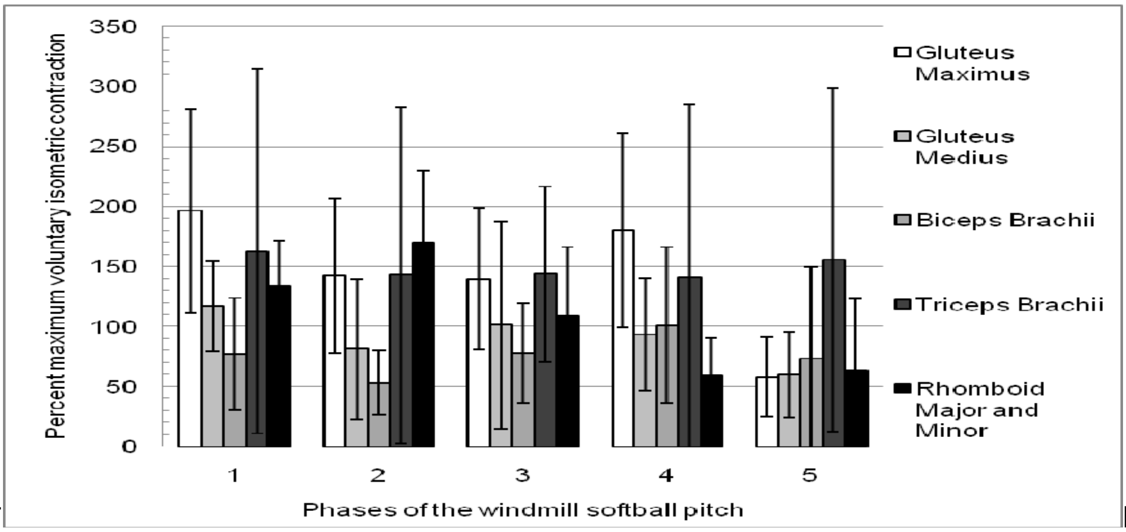

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Figure 2: Mean and Standard Deviations (error bars) of Muscle Activation During the Windmill Softball Pitch

DISCUSSION: The wind-up or Phase 1 displayed greater muscle activity in the gluteus medius and maximus than the upper extremity muscles. And based on the weight shift during this phase, activation of the gluteals is required. Phase 2, where the arm was elevated to 90^0 and take off occurred for the stride leg, the gluteus medius acted to stabilize and generate torque of the pelvis; the rhomboids had increased their firing during this phase in attempt to stabilize the scapula throughout arm elevation in the scapular plane. Previous investigations have noted that prior to fatigue overhead throwers have increased upward rotation of the scapula compared to non-overhead throwers, indicating altered movement of the scapula (Myers et al, 2005). However in a separate investigation, after pitching in a regular collegiate event/fatigue, the scapula exhibited decreased upward rotation and external rotation (Birkelo et al, 2003); after a swimming event, investigators noted similar findings in altered scapular motion (Scibek and Borsa, 2003). An unstable scapula or inefficient movement of the scapula during such a dynamic movement would predispose the glenohumeral joint to migrate superiorly, which is associated with impingement syndrome (Deutsch et al, 1996).

During Phase 3 the activity of the gluteus medius increased, and where the humerus was not only being elevated but also externally rotated the triceps brachii activity remained consistent. Phase 4 displayed a continuation of the triceps brachii activity, as well as decreased activation of the scapular stabilizers.
Contrary to baseball mechanics the biceps brachii is most active during the acceleration phase during the windmill softball pitch compared to the deceleration phase (Fleisig et al, 1999). In Phase 4 as the pitcher was attempting to "post" for ball delivery on the stride leg, the dominant gluteus medius must hold the dominant hip upright, while the pitcher is balanced on the stride leg. During Phase 5 the triceps brachii experienced high activation while the core musculature of the gluteus maximus and medius decreased in activation. Throughout Phases 1-3 the rhomboids stayed consistent to stabilize the scapulae, as the arm was dropping below 90^0 of elevation and the humerus was internally rotating the rhomboids decreased in activity. The triceps brachii had the most variability during the windmill softball pitch, this may suggest different abilities to control the acceleration and deceleration phases between the pitchers involved. Future investigations with a larger sample size may look into a differences and relationships between experience level and muscular activation throughout the phases.

It is known that softball is the same game as baseball, but on a smaller field. It has been found that the upper extremity distraction forces during pitching are very similar between the two sports (Barrentine et al., 1998). However, the major apparent difference is the pitching surface from which the pitchers throw. In baseball, the pitchers throw from a mound that allows gravity to assist with the movement, while in softball pitchers throw from a level surface without the assistance of gravity. The windmill softball pitcher has to 'post' during Phase 4 of the pitching cycle and throughout ball release. The posting activity is not assisted by the force of gravity or 'falling' from a pitching mound; however the softball pitcher leaps forward to gain momentum. The requirement of balance is displayed in the evidence of gluteal activation during the last phases of the pitching cycle, where the dominant gluteus medius is highly active.

CONCLUSION: We were able to identify muscle activation for the upper and lower extremity during the windmill softball pitch in post-pubescent females. It should be noted that our sample size was small, however the protocol performed has been previously validated (Maffet et al., 1997; Rojas et al., 2009) and the certified athletic trainer was sufficiently trained in sEMG data collection. Further investigations need to not only address a different population group, such as pre-pubescent or professional, but also examine the activation of the scapular stabilizers. As this is the only investigation of our knowledge looking at the rhomboids throughout the windmill softball pitch, we are not able to generalize on the functionality of the rhomboids throughout the windmill pitch. In addition further investigations are needed on the lower extremity. An investigation of both dominant and non-dominant lower extremity and core musculature would provide insight to the dynamic balance required to perform a windmill softball pitch.

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