EXAMINATION OF GLUTEAL MUSCLE FIRING and KINETICS OF THE LOWER EXTREMITY DURING THE WINDMILL SOFTBALL PITCH

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The purpose of this study was to examine the muscle activation and kinetic data of the lower extremity during the windmill softball pitch. Limited research has documented the lower extremity in the windmill softball pitch. Seven female post-pubescent softball players volunteered for the study. Pitchers were analyzed with surface electromyography and motion analysis software. There was no relationship observed between gluteal activation and ground reaction forces at SFP and maximum force. Only one investigation prior to this study reported ground reaction forces of windmill softball pitchers, however they did not examine the EMG activity.

KEY WORDS: ground reaction forces, sEMG, pitching mechanics

INTRODUCTION: In 2008, the Amateur Softball Association reported that 2.5 million fast-pitch players registered and of those, 1.3 million were reported as female post pubescent between the ages of 12 and 18 (Rojas et al., 2009). Regardless of the sport of softball being increasingly more popular, there has been limited research in the area of biomechanics and injury implications. The sport of baseball has been researched much more extensively. When comparing the two sports, the main difference is that softball is a scaled down version of baseball. Example, the softball pitcher throws from level ground 12.19 m from the batter and displays more of a leap in the delivery, whereas a baseball pitcher throws from an elevated mound 18.44 m from the batter and produces more of a stepping action for the delivery.

Previously, shoulder distraction forces have been examined for both baseball and softball pitchers. Distraction forces of 70% to 90% body weight at the shoulder have been reported in windmill softball pitchers (Barrentine et al., 1998; Werner et al. 2006). These distraction forces are comparable to those of baseball pitchers. It is the repeated application of these distraction forces that eventually implicate overuse injuries similar to those experienced in baseball pitching (Feltner, & Dapena, 1986; Fleisig, Andrews, Dillman, 1995; & Werner et al. 1993). To the researchers' knowledge only one study has been presented discussing the implication of lower extremity biomechanics during the windmill softball pitch.
Recently, stride foot ground reaction forces have been observed in windmill softball pitchers, where the findings were different from those of reported in baseball (Werner et al., 2005). It is believed that softball pitchers exhibit greater ground reaction forces because they are throwing from flat ground and exhibiting an abrupt deceleration stop upon ball release (Werner et al.,2005), whereas baseball pitchers pitch from an elevated mound. The lower extremity musculature must balance the core and upper extremity musculature in attempt to maintain the fluid motion of the pitch. The gluteal muscles are primary stabilizers of the core and therefore when the gluteals are not able to provide sufficient stability and energy transference the athlete is predisposed to injury. It was our purpose to examine muscle activation and kinetic data of the lower extremity during the windmill softball pitch. We anticipated that as the pitcher completes the delivery then ground reaction forces would increase, and gluteal muscle activation would be activated to control the lower extremity throughout the deceleration phase.

METHODS: Data Collection: Four collegiate and three high school female post pubescent softball pitchers (age 17.7 y ± 2.6; height 169 cm ± 5.4; mass 69.1kg ± 5.4) consented to participate. The study was granted Institutional Review Board approval. Surface electromyography (sEMG) data were collected on the muscle bellies of the dominant leg (non-stride leg) gluteus maximus and medius muscles using Myopac Jr 10 channel amplifier (RUN Technologies Scientific Systems, Laguna Hills, CA).

To determine maximum voluntary isometric contraction (MVIC) for the gluteal muscle group, manual muscle tests were performed three times for five seconds. The MVICs determined for both the gluteus maximus and medius were based on the work of Kendall et al (1993). The first and last second of each MVIC trial 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.

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. The pitching mound was positioned so that the participants stride foot would land on top of the 40 X 60 cm Bertec force plate (Bertec Corp, Columbus, Ohio) which was anchored into the floor. A total of five trials were recorded after they were deemed a successful strike. Both sEMG and force plate data were collected at a rate of 1000 Hz. Force plate, kinematic, and sEMG data were synchronized using Motion Monitor® (Innovative Sports Training, Chicago, IL).

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 from stride foot plant (SFP) to maximum force production. Stride foot plant to maximum force production encompassed final aspect of phase 4 and phase 5 of the five phases of the windmill pitch as defined according to Maffet et al. (1997) illustrated in Figure 1. Stride foot plant phase was determined by the first recording of force on the force plate through the maximum force delivered on the force plate. According to Werner et al. (2005) maximum ground reaction force occurs just prior to ball release, thus after maximum force is achieved, the ball is released and the pitcher begins their follow-through phase. Five trials of sEMG data for each subject were analyzed to determine average peak amplitudes for all muscles during the SFP.

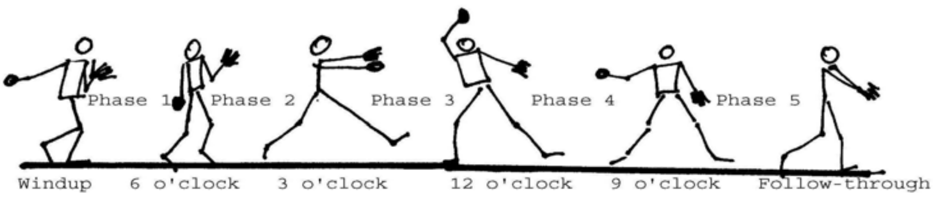

Figure 1. Windmill pitching phases.

RESULTS: *Surface EMG:* The gluteal muscles activation during SFP and maximum force or ball release are presented in Figure 2.

Kinetics: Breaking/propulsive, medial/lateral, and vertical ground reaction forces for the stride foot plant phase are presented in Figure 3. The force component Fx is in the direction of the pitch and can be interpreted as anterior/posterior force in reference to the body. The force Fy is the vertical component reflecting body weight support. Landing vertical forces peaked at ball release. The force Fz is the medial/lateral with lateral (positive) directed towards 3rd base for the right handed pitcher.

Pearson correlation results indicated weak and non-significant correlation between gluteus maximus activity and Fx (r=-0.38, p=0.18, r^2=0.14), Fy (r=0.22, p=0.46, r^2=0.05), and Fz (r=0.08, p=0.76, r^2=0.01). There were also weak and non-significant relationships between gluteus medius activity and Fx (r=-0.001, p=0.1, r^2<0.001), Fy (r=-0.12, p=0.72, r^2=0.01), and Fz (r=0.27, p=0.36, r^2=0.07).

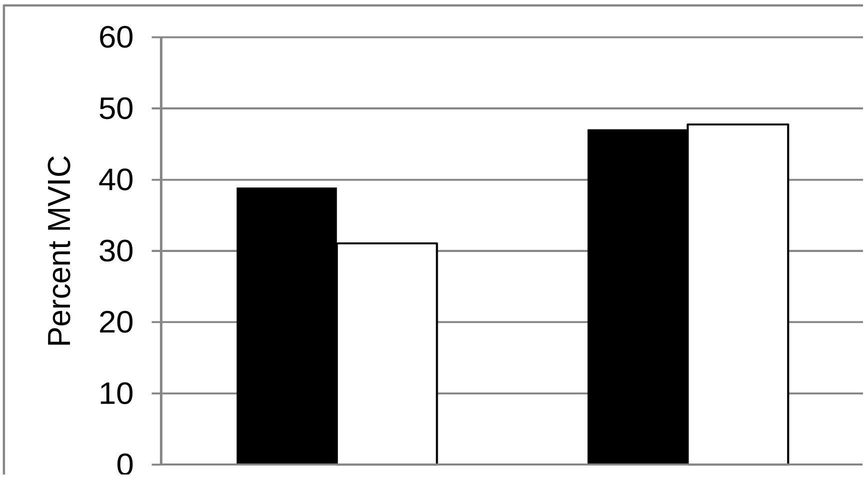

Figure 2: Gluteal activation during stride foot plant (SFP) and max ground reaction force (Max)

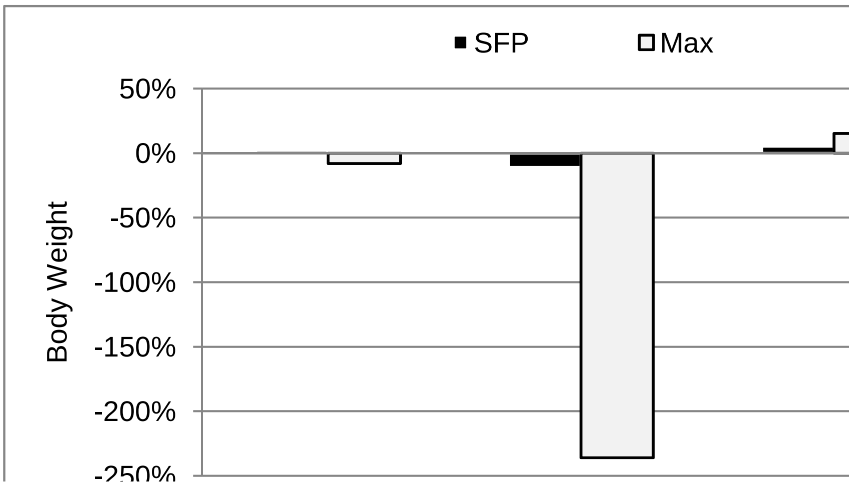

Figure 3. Representative (Fx) anterior/posterior forces, (Fy) vertical ground reaction forces, and (Fz) medial/lateral. Legend: SFP, stride foot plant; Max; maxium force.

DISCUSSION: The musculature of the lower extremity is important based on the theory of sequentiality (Putnam, 1993). According to Putnam (1993), proximal segments of the legs and trunk work sequentially in effort to accelerate the shoulder for optimal production in the upper extremity. During Phase 4, as the pitcher was attempting to abruptly decelerate for ball delivery on the stride leg, the dominant gluteus medius was attempting to hold the hip upright, while the pitcher was balanced on the stride leg. It is important that throughout the delivery that the gluteus medius is active to support the hip. If the gluteus medius is not active then the hip with drop predisposing the individual for muscular compensations and ultimately resulting in an overuse injury due to the breakdown in the kinetic chain (Kibler et al., 2006). Therefore, as more weight was applied to the stride leg, the gluteus medius increased activity. Kinetic data revealed that Fx was positive at SFP indicating the stride leg was attempting to maintain balance in order generate force in the direction of the ball. After SFP, the stride foot applied a breaking/posting force (Fy) in attempt to transfer energy to the upper extremity for ball release. This deceleration force was evident in a vertical ground reaction force of 235.96% body weight.

It has been shown that landing forces at the time of ball release correlated with wrist velocity during baseball pitching (MacWilliams et al., 1996). Thus, in throwing where forces are generated from the lower extremity to the upper extremity, leg drive is an important aspect. In addition, Werner (2005) found that peak deceleration forces of the stride were different from that of baseball pitching. In the current study the magnitude of peak vertical force was 235.96% of body weight.

CONCLUSION: We were able to identify muscle activation and kinetic data of the lower extremity during the windmill softball pitch in post-pubescent females. Our findings agreed with our postulation of the pitcher completing the pitch delivery with increased ground reaction forces as were their increases in the activation of the gluteal muscle group. Further investigations need to examine forces and torques of both the stride leg and non-stride leg during the pitching motion. Joint loads at the shoulder are known for producing overuse injuries for pitchers. However, more studies need to focus on the joint loads of the lower extremity in order to address the overuse injury potentials and their relationships to upper extremity injuries, especially concerning gluteal activation and core control.

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