GROUND REACTION FORCES, KINEMATICS, AND MUSCLE ACTIVATIONS DURING THE SOFTBALL PITCH

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Research has shown that ground reaction forces and lower extremity muscle activation are essential elements to the windmill softball pitch. Therefore, the purpose of this study was to quantify ground reaction forces, motion kinematics and muscle activations during the phases of stride foot plant to ball release of the windmill pitching motion. Ten female windmill softball pitchers participated. Fastballs for strikes were thrown and data revealed that as the windmill softball pitcher had increased ball velocity their vertical ground reaction forces also increased. As the medial forces increased the stride leg gluteus maximus had decreased activation. Proper conditioning of the lumbopelvic-hip complex, including the gluteals, is essential for injury prevention.

KEYWORDS: lower extremity, sEMG, softball pitching, segmental sequencing, vertical ground reaction force

INTRODUCTION: The sport of fast-pitch softball has become very popular for female athletes. It has been reported that during 2003 more than 2 million girls participated in the sport of softball (Guido et al., 2009). Despite its popularity, research regarding the sport has been limited. Previously, ground reaction forces have been examined in softball pitching because of the importance of the lower extremity throughout the pitching motion (Werner et al., 2005). Recently, Guido and colleagues (2009) reported on ground reaction forces and throwing mechanics in youth windmill softball pitchers and found during stride foot contact forces are generated anteriorly, medially, and vertically in attempt to break the forward momentum of the body and provide a base of support for trunk rotation and ball release. Data are yet to be reported on ground reaction forces, lower extremity kinematics, and muscle activations during the windmill softball pitch. Therefore the purpose of the study was to quantify ground reaction forces, motion kinematics, and muscle activations during the windmill softball pitch. It was hypothesized that there would be characteristic ground reaction forces, kinematics, and muscle activation patterns and that variations would be indicative of pitching velocity.

METHODS: Ten female windmill softball pitchers (17.6 ± 3.47 years, 166.9 ± 7.0 cm and 67.4 ± 12.2 kg) volunteered to participate in the study. All participants had recently finished their competitive high school spring softball seasons, and were deemed appropriately conditioned for participation. All testing protocols used in the current study were approved by the University's Review Board.

Participants reported for testing prior to engaging in resistance training or any vigorous activity that day. Location of the right and left gluteus maximus as well as the right and left gluteus medius were identified through palpation. Identified locations for surface electrode placement were shaved, abraded and cleaned using standard medical alcohol swabs. Subsequent to surface preparation, adhesive 3M Red-Dot bipolar surface electrodes (3M, St. Paul, MN) were attached over the muscle bellies and positioned parallel to muscle fibers using techniques described by Basmajian and Deluca (1985). Once all electrodes had been secured, manual muscle tests (MMT) were conducted using techniques described by Kendall et al.(1993). Manual muscle testing was conducted to establish baseline readings for each participant's maximum voluntary isometric contraction (MVIC) to which all sEMG data would be compared.

Surface electromyographic (sEMG) data were transmitted to The MotionMonitor™ motion capture system (Innovative Sports Training Inc, Chicago IL), through a Noraxon Myopac 1400L 8-channel amplifier. The signal was full wave rectified and smoothed based on the smoothing algorithms of root mean squared at windows of 100 ms. Throughout all testing, sEMG data were sampled at a rate 1000 Hz. In addition, all sEMG data were notch filtered at frequencies of 59.5 Hz and 60.5 Hz respectively (Blackburn and Pauda, 2009).

Kinematic and kinetic data were collected using The MotionMonitor™ motion capture system (Innovative Sports Training, Chicago IL). Prior to completing test trials, participants had a series of ten electromagnetic sensors attached at the following locations: (1) the medial aspect of the torso at C7; (2) medial aspect of the pelvis at S1; (3) the distal/posterior aspect of the throwing humerus; (4) the distal/posterior aspect of the throwing forearm; (5) the distal/posterior aspect of the non-throwing humerus; (6) the distal/posterior aspect of the non-throwing forearm; (7) distal/posterior aspect of stride lower leg; (8) distal/posterior aspect of the upper stride leg; (9) distal/posterior aspect of non stride lower leg; and (10) distal/posterior aspect of non stride upper leg (Myers et al., 2005). Following the attachment of the electromagnetic sensors, an eleventh sensor was used to digitize the bony landmarks.

Following all set-up and pre-testing protocols, participants were allotted an unlimited time to perform their own specified pre-competition warm-up routine. During this time, participants were asked to spend a small portion of their warm-up throwing from the indoor pitching surface to be used during the test trials. After completing their warm-up and gaining familiarity with the pitching surface, each participant threw a series of maximal effort fastballs for strikes toward a catcher located the regulation distance (12.2 m). The pitching surface was positioned so that the participant's stride foot would land on top of a 40 x 60 cm Bertec force plate (Bertec Corp, Columbus, Ohio) which was anchored into the floor. For the current study, those data from the fastest pitch passing through the strike-zone were selected for detailed analysis. Pitch velocity was determined by JUGS radar gun (OpticsPlanet, Inc., Northbrook, IL) positioned at the base of the pitching surface and directed towards home plate.

Raw data regarding sensor orientation and position were transformed to locally based coordinate systems for each of the respective body segments. Euler angle decomposition sequences were used to describe both the position and orientation of the torso relative to the global coordinate system (Wu et al., 2002; Wu et al., 2005). The use of these rotational sequences allowed the data to be described in a manner that most closely represented the clinical definitions for the movements (Myers et al., 2005).

Data were analyzed in the current study using the statistical analysis package SPSS 15.0 for Windows. Data for the fastest strike mean and standard deviation, for all sEMG and kinematic and kinetic parameters were calculated. Phase 1, was defined as the start of pitching motion to the top of back swing (TOB). Phase 2, was from TOB to stride foot plant (SFP). Phase 3 was from SFP to ball release (BR), and Phase 4 was from BR to the completion of follow through.

RESULTS: Means and standard deviations of kinematic, kinetic and sEMG data are presented in Figures 1-3. Average ball velocity reported was 24.1$\pm$1.38 m/s.

DISCUSSION: This is the first study to investigate ground reaction forces, kinematics and sEMG of the windmill softball pitch. It is evident that the participants in the current study generated large breaking forces and vertical forces to drive toward the plate in order to generate the greatest ball velocity (Figure 1). Breaking forces revealed on the average 35.9%$\pm$10.3%BW for all participants. However, when examining stride length, those with greater stride length, as defined by TOB occurring prior to SFP, demonstrated breaking forces of 31.5%$\pm$12.5%BW compared to 41.4%$\pm$8.5%BW respectively. When examining vertical forces, the average was 179%$\pm$38.2%BW; however, those with longer strides did exhibit greater vertical forces than those with shorter stride lengths. It has been reported that those with longer stride lengths have greater ball velocity (Guido at al., 2009); however, in the current study those with longer stride lengths had on average 0.51m/s slower velocity than those with shorter stride lengths. Those with higher velocities exhibited higher vertical ground reaction forces than those with lower velocities.

Gluteal muscle activations of the stride leg during Phase 3 of the softball pitching motion demonstrated pelvis stabilization and torque generation in preparation for ball release (Figure 2). Typically the gluteal muscle group provides stabilization when on single leg support. Pelvic stabilization is important for efficient energy transfer up the kinetic chain from the hips to the pelvis and scapula on to the shoulder, elbow, hand and wrist for ball release. This action is evident by the presented relationship of the non stride leg gluteus maximus having greater activation in those with greater ball velocities. In addition, as the medial (Fz) forces increased, stride leg gluteus maximus had decreased activation. This is important to note in that as there were greater medial forces at the lower extremity on the stride leg, the stride leg gluteus medius had decreased activation. The gluteus maximus acts to extend the hip and then allows for external rotation of the hip. The decreased activation of the gluteus maximus on the stride leg indicates that it was not as active in externally rotating the stride hip thus resulting in increased medial ground reaction forces. The lack of gluteal activity was evident by the great amount of stride knee abduction at foot contact (Figure 3).

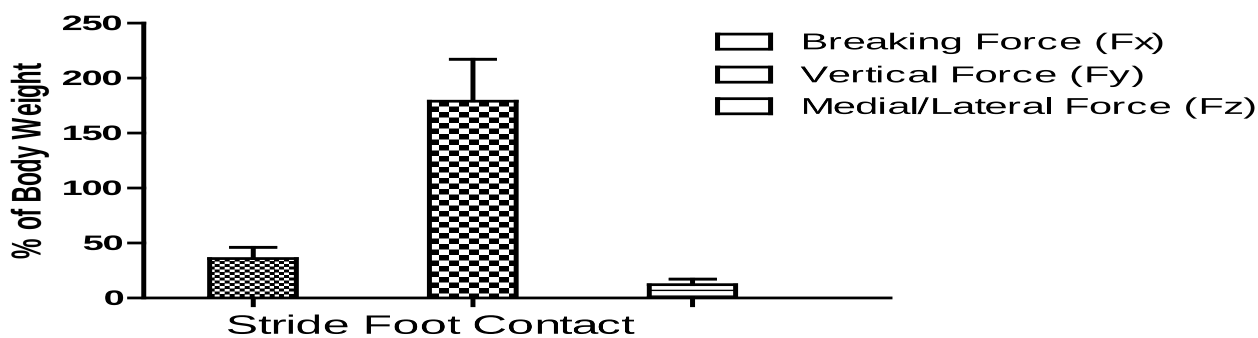

Figure 1. Means and standard deviations of ground reaction force magnitude at stride foot contact presented as a percent of the participant's body weight.

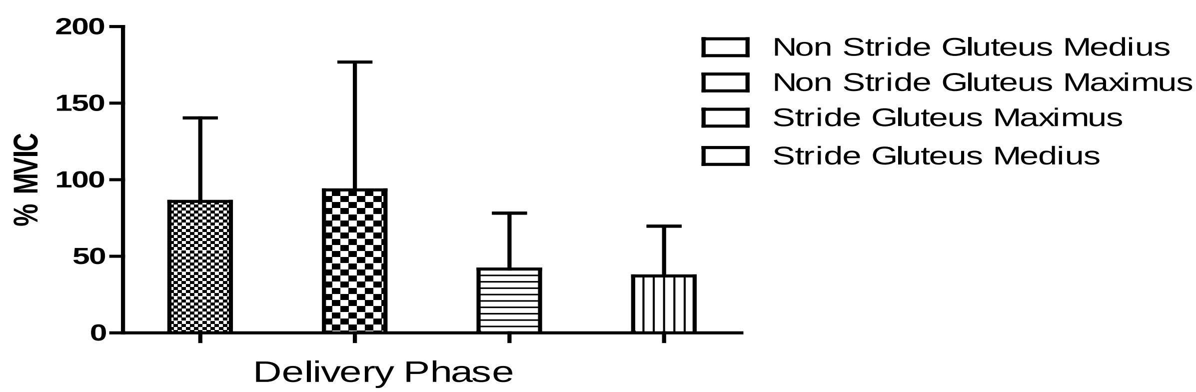

Figure 2. Means and standard deviations of the gluteal musculature, as presented as a percent of their MVIC, during the delivery phase of the windmill pitching motion.

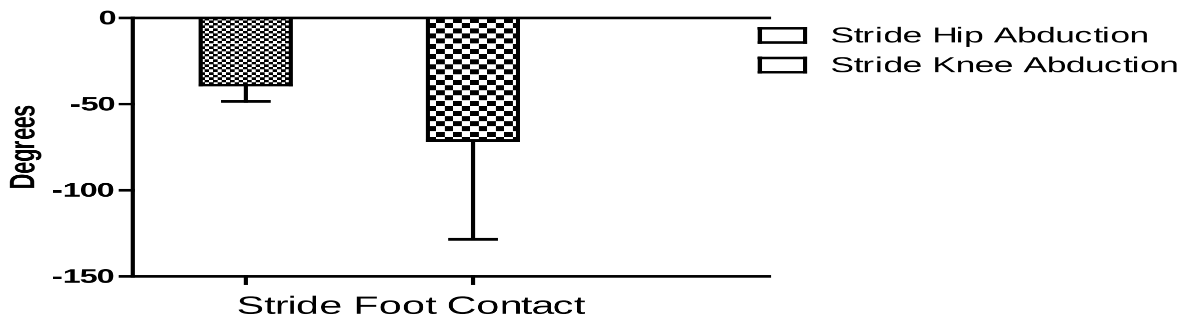

Figure 3. Means and standard deviations of lower extremity kinematic parameters of the stride leg hip and knee as presented in degrees experienced at stride foot contact.

CONCLUSIONS: Data revealed that as the windmill softball pitcher increased ball velocity their vertical ground reaction forces also increased. Thus, further studies are warranted examining the muscle activations of the lower extremity and their importance in the effectiveness of the windmill softball pitch. However, from the data presented, it is evident that strength and conditioning of the gluteal muscle group bilaterally is salient in the windmill softball pitch.

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