A KINEMATIC DESCRIPTION OF THE POST PUBESCENT WINDMILL SOFTBALL PITCHING MOTION

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The purpose of this study was to describe the kinematics of the windmill softball pitch. Throughout the first three phases of the movement, both the pelvis and the trunk were rotated to a closed position while the throwing shoulder was flexed and externally rotated, and the throwing elbow was flexed. During the latter stages of the movement, the pelvis and torso opened up to face the plate, the throwing shoulder moved through an arc of hyperextension and was internally rotated while the throwing elbow extended. The kinematics identified may contribute to overuse injuries commonly reported by post pubescent softball pitchers. However, due to the limited data describing the windmill softball pitch, addition research is needed.

KEY WORDS: pitching, kinematics, post pubescent, softball, windmill.

INTRODUCTION: Similar to the baseball pitch, the windmill softball pitch has been labelled as a major contributing factor in upper extremity overuse injuries to pitchers (Hill et al., 2004; Maffet et al., 1997; Rojas et al., 2009; Werner et al., 2005; Werner et al., 2006). However, unlike with baseball pitching, there is limited research available that describes the windmill softball pitch in full. Since post pubescent softball pitchers often throw up to 2000 pitches in a weekend (Werner et al., 2006), it is important to understand their pitching mechanics from a biomechanical perspective. To date, the authors have identified only one study describing the kinematics of collegiate softball pitchers (Barrentine et al., 1986). Thus, the purpose of this study was to quantify the biomechanics specific to the pitching motion in post pubescent softball pitchers. In doing so, this study attempts to aid in the development of a fundamental basis for how post pubescent pitchers perform as well as how arm injuries may be sustained during performance.

METHODS: Data Collection: Four collegiate and three high school female post pubescent softball pitchers (age 17.7 $\pm$ 2.6; height 169cm $\pm$ 5.4; mass 69.1kg $\pm$ 5.4) participated in the current study. Data collection sessions were conducted at the University of Arkansas HPER building and testing protocols were approved by that institution's ethics board. Prior to testing each pitcher provided consent.

Kinematic data were collected using The Motion Monitor® system (Innovative Sports Training, Chicago IL) and calculated using the ISB recommendations of the international shoulder group (Wu et al., 2005). Prior to the conduction of test trials, the space in which the pitchers were to throw was calibrated using the following protocol. The origin of the world axes system was located on a wooden platform located 25.4 cm from the extended range transmitter used to generate the electromagnetic field. The orientation of the world axis system was similar to that described by Wu and Cavanaugh (1995) and was such that the world x-axis extended from the center of the pitching rubber toward the center of home plate, the world y-axis extended was orthogonal to the x-axis and extended vertically from the center of the pitching rubber. The world z-axis was orthogonal to both x and y, directed laterally to the right. To calibrate the space, a wooden stylus was attached to an electromagnetic sensor and placed at the world axes system origin, 15 cm from the origin along both the x and z axes, and at one random position above the origin per manufacturer recommendations. Following the establishment and calibration of the world axes, the root mean square error in calculating the three-dimensional location of markers within the calibrated space was determined to be less than 20 mm. In addition to kinematic data, force data were collected to identify when stride foot plant occured. To collect force data, a 40 x 60 cm Bertec force plate (Bertec Corp, Columbus, OH) was recessed into the platform at the location where stride foot plant was to occur.

Once set-up was complete and the system and space were calibrated, electromagnetic sensors were placed on the thorax, sacrum, distal throwing forearm, right and left mid-humerus, and right and left mid-shank of each subject and unlimited time was allotted for the participants to warm-up based on their normal routine. Following the warm-up, each participant threw fastball windmill style deliveries using an official softball (12 in. circumference, 0.17 kg) to a catcher behind the plate 12.2 m away. Both kinematic and force data were collected at a rate of 1000 Hz and were synchronized using Motion Monitor® (Innovative Sports Training, Chicago, IL). A total of five trials were recorded after they were deemed a successful strike and between trials, pitchers were allowed a 40-60 s rest period.

Data Analysis: After completion of the trials, positional kinematic data were filtered independently along the x, y, and z-axis using a Butterworth filtering techniques described by Werner et al. (2005) with a cut off frequency of 13 Hz. For analysis the movement was divided into the five phases described in Figure 1 and defined by Maffet et al. (1997). Although the softball pitch typically incorporates six phases, this study focused on all activity prior to ball release and at ball release. Throwing kinematics were calculated using the Internation Society of Biomechanics recommendations for reporting joint motion (Wu et al., 2005) and included forward and lateral flexion of the trunk, axial hip and trunk rotation, shoulder flexion, shoulder internal rotation, elbow flexion, and forearm pronation.

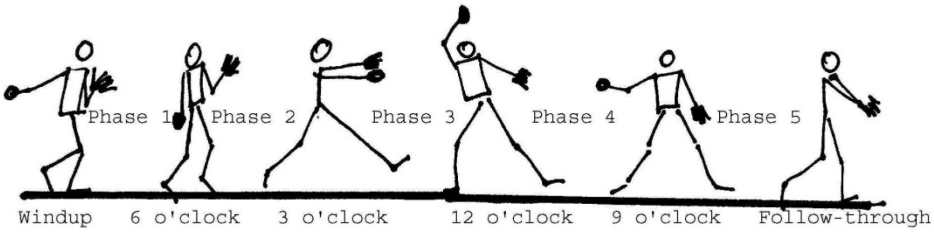

Figure 1: Windmill pitching phases.

RESULTS: During the pitch cycle, the hips close to a peak angle of -80° at 12 o'clock, before rotating open to an angle of -25° at ball release. Rotation of the upper torso follows a nearly identical pattern throughout the pitch cycle with the shoulder closing to an angle of -75° at 12 o'clock before rotating open to an angle of -17° at ball release. From 6 o'clock to 12 o'clock, the throwing shoulder is flexed to near 180° and externally rotated to -38°. From 12 o'clock through release, the throwing shoulder is moved through the near 180° arc of hyperextension back to an angle near 0°, as well as being internally rotated to an angle of -5°. In addition, the throwing elbow is initially hyper extended to an angle of -2° at 6 o'clock before being flexed to 26° at 12 o'clock. From here through release, the elbow was extended, reaching an angle of 4° at release. Also from 6 o'clock through 12 o'clock, the throwing forearm was pronated to 41° before being supinated back to an angle of 6° at release. The magnitudes for kinematic paramters at 6 o'clock, 12 o'clock, and release are presented in Table 1.

Table 1 Mean and standard deviation values for kinematic parameters at 6 o'clock, 12 oclock, and release

Parameter	6 o'clock	12 o'clock	release
hip rotation (^{o})	-12 ± 6	-80 ± 26	-25 ± 9
shoulder rotation (^{o})	-5 ± 7	-75 ± 22	-17 ± 11
shoulder flexion (^{o})	0 ± 2	164 ± 16	3 ± 4
shoulder internal rotation (^{o})	34 ± 16	-38 ± 15	-5 ± 8
elbow flexion (^{o})	-2 ± 4	26 ± 18	4 ± 6
forearm pronation (^{o})	18 ± 11	41 ± 29	6 ± 10

DISCUSSION: The sport of fast pitch softball is essentially a scaled down version of baseball which allows for comparisons across the two sports to be made. In terms of pitching, it has been the common perception that the windmill pitching motion in softball is a 'more natural movement' than the baseball pitching motion. This view has led to the opinion that the underhand motion is less stressful on the arm and may be the reason that softball pitching is less studied than baseball pitching. However, it has been found that the major kinematic and kinetic characteristics associated with pitching mechanics are similar across the two sports (Barrentine et al., 1998; Werner et al., 2006).

One common injury reported by post pubescent softball pitchers is anterior shoulder pain (Barrentine et al., 1998). The etiology of this pain may be related to both mechanical and musculoskeletal characteristics observed in female softball pitchers. First, during the initial phases (Phase 2 and 3) of the movement (i.e. 6 o'clock to 12 o'clock in softball) the throwing shoulder is both flexed and externally rotated. This high angle of shoulder flexion, coupled with the observed external shoulder rotation in softball pitchers may result in elevated anterior forces that may contribute to anterior/superior translation of the humeral head. This humeral translation has the potential to result in subacromial impingement injuries as well as posterior shoulder impingement injuries in post pubescent softball pitchers.

Another possible scenario for anterior shoulder problems in softball pitchers may result from a combination of both mechanical characteristic at the shoulder and elbow, and deficiencies in muscular strength in the bicep. Women typically exhibit less muscle mass and strength in the upper torso and arms when compared to their male counterparts (Miller, A.E. et al., 1993). As shown in Table 1, the elbow remains in a position near full extension throughout the windmill pitch. This, coupled with the large rotational arc of the arm throughout the movement may result in increased distraction forces at the shoulder (Barrentine et al., 1998). To resist this distraction the muscles of the rotator cuff, along with the biceps brachii fire to stabilize the head of the humerus against the glenoid fossa of the scapula (Glousman et al., 1988). As a result of this repeated increase in biceps activity, post pubescent softball pitchers may be at a greater risk of developing chronic tendonitis of the biceps and/or injury to the biceps labrum complex. It has also been reported that subacromial impingement may be a major factor in contributing to primary disease of the rotator cuff (Neer 1983). If the kinematics of softball pitching do contribute to subacromial impingement that resuls from incereased superior humeral translation, softball pitchers may experience repetitive microtrauma to the very muscles responsible for stablizing the humerus.

CONCLUSION: This study provides a kinematic description of the post pubescent windmill pitching motion. Although the data in the current study agree with previous reports (Barrentine, et al., 1998; Werner et al., 2006) in describing the actions occurring throughout the movement, they also identify some of the key factors that may be associated with the anterior shoulder pain commonly reported by post pubescent softball pitchers. In addition, this study, along with Barrentine et al., (1998) and Werner et al., (2006) shows that studies of the windmill softball pitch can be conducted in similar fashion to those for baseball pitching. Thus, because of the limited amount of literature currently available that describes the windmill softball pitch, further investigation into the etiology of injury, as well as the differences between genders and ages is needed.

REFERENCES:

Barrentine, S. Fleisig, G., Whiteside, J., Escamilla, R.F., & Andrews, J.R. (1998). Biomechanics of windmill softball pitching with implications about injury mechanisms at the shoulder and elbow. *Journal of Orthopedic and Sports Physical Therapy*, 28, 405-415.

Glousman, R., Jobe, F., Tibone, J., Moynes, D., Antonelli, D., & Perry, J., (1988). Dynamic electromyographic analysis of the throwing shoulder with glenohumeral instability. *Journal of Bone and Joint Surgery, 70,* 220-226.

Miller, A.E., MacDougall, J.D., Tarnopolsky, M.A., & Sale, D.G. (1993). Gender differences in strength and muscle fiber characteristics. *European Journal of Applied Physiology and Occupational Physiology,* 66, 254-262.

Neer CS: Impingement lesions. Clinical Orthopedics 173: 70–77, 1983

Rojas, I.L., Provencher, M.T., Bhatia, S., Foucher, K.C., Bach, B.R., Romeo, A.A., Wimmer, M.A., & Verma, N.N. (2009). Biceps activity during windmill softball pitching. *American Journal of Sports Medicine*, 37, (3), 558-565.

Werner, S.L., Guido, J.A., McNeice, R.P., Richardson, J.L., Delude, N.A. & Stewart, G.W. (2005) Biomechanics of youth windmill softball pitching. *American Journal of Sports Medicine*, 33 (4), 552-560.

Werner, S.L., Jones, D.G., Guido, J.A., & Brunet, M.E. (2006). Kinematics and kinetics of elite windmill softball pitching. *American Journal of Sports Medicine*, 34, (4), 597-603.

Wu, G., & Cavanagh, P.R. (1995). ISB recommendations for standardization in the reporting of kinematic data. *Journal of Biomechanics,* 28, 1257-1261.

Wu, G., van der Helm, F.C.T., Veeger, H.E.J., Makhsous, M., Van Roy, P., Anglin, C., et al. (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.

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