PITCHING MECHANICS AND PAIN HISTORY IN COLLEGIATE SOFTBALL PITCHERS

Gretchen Oliver[1], Gabrielle Gilmer[1], Kenzie Friesen[1], Abigail Brittain[1], Adam Anz[2], Michael Goodlett[3], Jeff Dugas[4], and James Andrews[2]

School of Kinesiology, Auburn University, Auburn AL, USA[1]
Andrews Institute for Orthopaedics and Sports Medicine, Gulf Breeze FL, USA[2]
Auburn University Sports Medicine, Auburn University, Auburn AL, USA[3]
Andrews Sports Medicine and Orthopaedic Center, Birmingham AL, USA[4]

The purpose of this study was to compare collegiate softball pitchers' mechanics with and without upper extremity pain. Fifty-five collegiate softball pitchers volunteered to participate. Based on a pain history questionnaire, participants were divided into two groups: upper extremity pain, and pain free. Kinematic data were collected on the change-up softball pitch using an electromagnetic tracking system. The group exhibiting upper extremity pain illustrated greater shoulder horizontal abduction at foot contact, and less trunk lateral flexion towards the throwing side at ball release compared to the pain free group. In combination, the authors speculate these injury-prone positions and forces about the shoulder could be the result of improper energy transfer along the kinetic chain.

KEYWORDS: injury, fast pitch softball, windmill softball pitch

INTRODUCTION: Limited data are available on pain history and pitching mechanics in fastpitch softball. Of the paucity of softball data available, none have attempted to examine pain history and pitching mechanics. Approximately 370 overuse injuries were reported in collegiate and high school fastpitch softball players from 2004-2009 (Roos, 2015). This injury rate equates to approximately one injury per 10,000 athletic exposures, with 82.5% of these being shoulder injuries (Krajnik, 2010). Although these upper extremity injury rates are known, fastpitch softball has yet to regulate pitchers' volume of throwing with pitch counts or limited inning and consecutive game exposure.

Anterior shoulder pain is a common symptom of overuse and has been hypothesized to be a result of the increased forces during the acceleration phase of the windmill softball pitch. The acceleration phase is considered from the top of back swing (arm directly overhead) to ball release (Barrentine, 1998; Werner, 2005; Werner 2006). With limited data regarding softball pitching, there are yet to be studies describing the pitching mechanics of those sustaining upper extremity pain.

Because of the increased participation and high injury susceptibility, it was the purpose of this study to investigate pitching mechanics and upper extremity pain in National Collegiate Athletic Association (NCAA) Division I softball pitchers. Specifically, the authors examined the differences between kinematics of the trunk, shoulder, and elbow of those with and without upper extremity pain. It was hypothesized that pitchers with upper extremity pain would have pathomechanics along the kinetic chain when compared to those without pain.

METHODS: Fifty-five NCAA Division I softball pitchers (20.0 ± 1.3 yrs.; 173.4 ± 6.9 cm; 80.3 ±12.6 kg; 10.5 ± 2.6 yrs. of experience) were recruited to participate. All participants were active pitchers of a NCAA Division I softball team, and medically cleared for competition. The University's Institutional Review Board approved all testing protocols. Informed written consent was obtained from each participant before testing.

Participants completed a pain history questionnaire and were grouped based on the 'yes'/'no' response to the question, "Do you currently experience any pain/discomfort?". If 'no' was answered, participants were deemed pain free (19.9 ± 1.4 yrs; 173.8 ± 6.9cm; 81.4 ± 12.5kg; 10.0 ± 2.5 yrs. of experience; n = 32). If the answer was 'yes', they were to select the area of the body where they experienced pain. Participants answering 'yes' and selecting anything in the shoulder, elbow, forearm, area were designated to the pain group (20.0 ± 1.3 yrs; 174.4 ± 6.9cm; 82.9 ± 12.4kg; 11.1 ± 2.6 yrs. of experience; n = 23).

Following the pain history questionnaire, 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). Eleven electromagnetic sensors were attached to the following locations: (1) posterior aspect of the torso at the first thoracic vertebrae (T1) spinous process; (2) posterior aspect of the pelvis at the first sacral vertebrae (S1); (3) flat, broad portion of the acromion on the throwing arm scapula; (4-5) lateral aspect of bilateral upper arm at the deltoid tuberosity; (6-7) posterior aspect of bilateral distal forearm, centered between the radial and ulnar styloid processes; (8-9) lateral aspect of bilateral upper leg, centered between the greater trochanter and the lateral condyle of the knee; and (10-11) lateral aspect of bilateral lower leg, centered between the head of the fibula and lateral malleolus. A twelfth, moveable sensor was attached to a plastic stylus used for the digitization of bony landmarks. In order to ensure accurate identification and palpation of bony landmarks, the participant stood in anatomical neutral throughout the duration of the digitization process. Using the digitized joint centers for ankle, knee, hip, shoulder, T12-L1, and C7-T1, a link segment model was developed. Joint centers were determined by digitizing the medial and lateral aspect of a joint then calculating the midpoint between those two points (Oliver, 2010a; Oliver 2010b; Wu, 2002; Wu, 2005). The ankle and knee joints were defined as the midpoint between the digitized medial and lateral malleoli and medial and lateral femoral condyles, respectively, whereas the spinal column was defined as the digitized space between C7-T1 and T12-L1. The shoulder joint center was calculated from the rotation of the humerus relative to the scapula while the hip joint centers were calculated from the rotation of the femur relative to the pelvis (Haung et al., 2010). 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. Sensor data were independently filtered along each global axis using a 4th order Butterworth filter with a cutoff frequency of 13.4 Hz. All data were time stamped through The MotionMonitor® and passively synchronized using a data acquisition board.

After sensor attachment and digitization, each participant was allotted an unlimited amount of time to warm-up and become familiar with all testing procedures. Participants were then instructed to throw three change-up pitches for strikes to a catcher 13.11 m (43 feet) away.

The pitching motion was defined by five events: (1) start of the pitching motion (when pitching arm was at 90º of forward flexion, (2) top of back swing (TOB), (3) foot contact (FC), (4) ball release (BR), and (5) follow through (FT) (Figure 1). All kinematic data were compared at the events of TOB, FC, BR and FT.

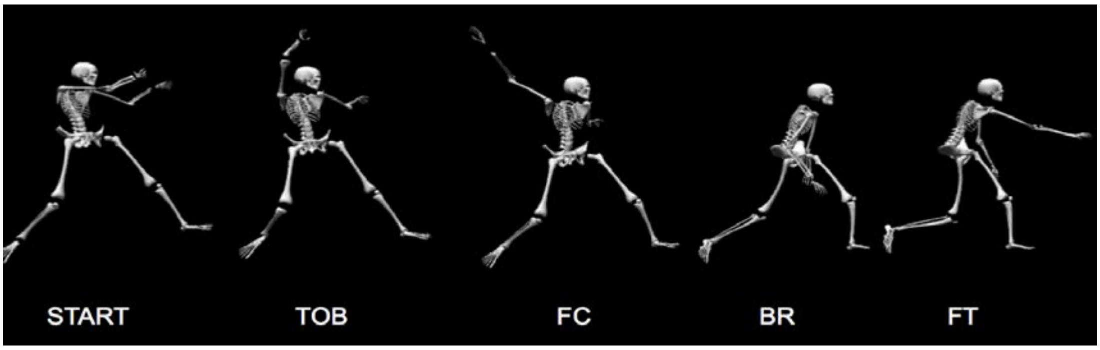

Figure 1: Events of the pitching motion. START= Start of pitching motion; TOB = Top of back swing; FC = Foot contact; BR = Ball release; FT = Follow through.

RESULTS: All data were processed using a customized MATLAB (MATLAB R2010a, MathWorks, Natick, MA, USA) script. Statistical analyses were performed using IBM SPSS Statistics 22 software (IBM Corp., Armonk, NY) with an alpha level set *a priori* at $\alpha = 0.05$. Prior to analysis, Sharpio-Wilks tests of normality were run and results showed the data were non-normally distributed. Mann Whitney U-tests were employed to examine the differences between the pain and pain free group in stride length; trunk flexion, rotation, and lateral flexion; shoulder horizontal abduction and elevation; and elbow flexion. Median values for the kinematic variables amongst pain and pain free groups are shown in Table 1. Significant difference were revealed in shoulder horizontal abduction at FC ($p = 0.014$, $U = 153$, $Z = 2.450$) and trunk lateral flexion at BR ($p = 0.012$, $U = 150$, $Z = -2.515$). Specifically, the pain group revealed significantly greater shoulder horizontal abduction at FC and significantly less trunk lateral flexion (towards the throwing arm) at BR. Stride length between the pain and pain free groups resulted in 45.7% and 47.6% of height, respectively. The results showed no significant differences among the other kinematic variables.

Table 1: Kinematic Variable Medians (∘) for the Pain and Pain Free Groups

Kinematic Variable	Group	TOB	FC	BR	FT
Trunk Flexion	Pain	6	16	16	12
	Pain Free	8	10	14	14
Trunk Rotation	Pain	68	70	44	22
	Pain Free	58	68	34	22
Trunk Lateral Flexion	Pain	4	12	12*	12
	Pain Free	4	10	22*	28
Shoulder Horizontal Abduction	Pain	68	124*	66	24
	Pain Free	62	106*	74	30
Shoulder Elevation	Pain	152	116	28	60
	Pain Free	152	108	16	58
Elbow Flexion	Pain	56	62	78	64
	Pain Free	84	56	64	58

DISCUSSION: As hypothesized, there were significant differences in the pitching kinematics between collegiate softball pitchers with a history of upper extremity pain and those who were considered pain free. The pitching kinematics in the current study are consistent with what has previously been found in elite softball athletes (Werner 2006). The difference in greater shoulder horizontal abduction at FC indicates that the pain group positioned their arm further from the body during the acceleration phase of the pitch. Werner et al. (2006) evaluated pitching mechanics in 24 Olympic softball pitchers throwing a rise pitch. In their cohort, abduction at FC measured 155° ± 16°. However, it should be noted that previous softball pitching studies examined the fastball and rise-ball (Oliver, 2010; Werner, 2005;

Werner, 2006) with no previous evaluation of the change-up softball pitch. Thus, comparisons of pitching mechanics are limited.

At BR, the pain free group was significantly more rotated towards the throwing side when compared to the pain group. There are limited data on ideal movement of the trunk during a softball windmill pitch, however, during an overhead throw, the most efficient energy transfer is achieved as the body rotates more towards the throwing side. The pain group illustrated a trunk lateral flexion of 12º at BR and the no-pain group illustrated a trunk lateral flexion of 22º. Assuming that overhead throwing mechanics are comparable to the windmill softball pitch, this finding suggests that the pain free group transfers energy more efficiently from the lower extremity to the upper extremity. Specifically, this finding implies that proximal instability of the kinetic chain could be a predisposing pain factor based on the mechanics displayed by the pain group.

CONCLUSION: This study suggests that pitchers with upper extremity pain display mechanical differences pitching the change-up when compared to those pitching pain free. These mechanical differences exhibited could be the results of many factors, however, it is known that inefficient proximal stability of the kinetic chain results in alteration of energy transfer to the more distal upper extremity and thus potentially predisposing pain. Future studies should seek to better understand the relationship between these mechanical differences of those pitching with pain and those pain free and the susceptibility of pain and injury.

REFERENCES:

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

Haung, Y.H., Wu, T.Y., Learman, K.E. Tsai, Y.S. (2010). A comparison of throwing kinematics between youth baseball players with and without a history of medial elbow pain. *Clinical Journal of Physiology*, 53, 160-166.

Krajnik, S., Fogarty, K.J., Yard, E.E., Comstock, R.D. (2010) Shoulder injuries in US high school baseball and softball athletes, 2005-2008. *Pediatrics,*125, 497-501.

Oliver, G.D., Dwelly P.M., Kwon, Y.H. (2010). Kinematics motion of the windmill softball pitch in prepubescent and pubescent girls. *Journal of Strength and Conditioning Research,* 24: 2400-2407.

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.

Roos, K.G., Marshall, R., Kerr, Z.Y., Golightly, Y.M., Kucera, K.L., Myers, J.B., Rosamond, W.D. (2015). Epidemology of overuse injuries in collegiate and high school athletics in the United States. *American Journal of Sports Medicine,* 43, 1790-1797.

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, 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, 597-603.

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.