QUANTITATIVE ANALYSIS OF THROWING MECHANICS IN SOFTBALL POSITION PLAYERS

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The purpose of this study was to thoroughly describe the biomechanics of the throwing motion of collegiate softball infielders, catchers, and outfielders. Eighteen Division I National Collegiate Athletic Association softball players (19.2 ±1.0 y; 68.9 ±8.7 kg; 168.6 ±6.6 cm) who were listed on the active playing roster and deemed free of injury for the past 6 months volunteered to participate. Kinematic and kinetic data were collected with an electromagnetic tracking system via the MotionMonitor™ and calculated as per ISB recommendations. Of all the kinematic and kinetic variables, there where no significant differences between different position players and the throwing events. There was a significant difference in the catcher's shoulder plane of elevation when compared to the other two position players when examining the entire throw ($p=0.03$).

KEY WORDS: kinetic chain; motion analysis; fast-pitch softball.

INTRODUCTION: During 2010-2011, the National Federation of State High School Associations (2012) reported 385,028 fast pitch softball participants, resulting in a 4% increase in participation from 2008-2009. It was also reported that softball ranked as the fourth most popular high school sport for girls. Though there has been an increase in participation, there are limited data regarding the throwing mechanics of softball players. Much of the literature focuses the mechanics of pitching (Barrentine, Fleisig, Whiteside, Escamilla, & Andrews, 1998; Werner, Guido, McNeice, 2005; Werner, Jones, Guido, & Brunet, 2006; Guido, Werner & Meister, 2009; Rojas, Provencher, Bhatia, Foucher, Bach, Romeo, Wimmer, & Verma, 2009; Oliver, Dwelly, & Kwon, 2010). It has been reported that there is a sequential activation of proximal-to-distal segments of the trunk, shoulder, elbow, and wrist when performing the windmill softball pitch in experienced players (Oliver et al., 2010) just as there is in overhead throwing (Putnam, 1993). In addition it has been reported that alterations in this sequential motion could result in not only decreased ball velocity (Oliver et al., 2010) but also an increased susceptibility for injury (Kibler, 1998; McMullen & Uhl, 2000; Kibler & Sciascia, 2006).

Previously, joint motions and movement patterns of the kinetic chain during the windmill softball pitch have been described sequentially from proximal to distal (Oliver et al.,2010). Though data are beginning to evolve on windmill softball pitching, there are no data available on the windmill softball positional players. Therefore, it was the purpose of this study to thoroughly describe the biomechanics of the throwing motion of collegiate softball infielders, catchers, and outfielders. In attempt to quantify the throwing mechanics, the softball players were to perform positional throws in attempt to prevent a runner from advancing to second base. Thus infielders received a simulated ground ball and threw to second; outfielders received a simulated fly ball and threw in to second, while catchers received a simulated pitch and threw down to second. It was hypothesised that catchers would have significantly different throwing mechanics, when throwing to second, than the other positional players due to the nature of their squatted position and transition time to a vertical throwing position.

METHOD: Eighteen Division I National Collegiate Athletic Association softball players who were listed on the active playing roster and deemed free of injury for the past 6 months volunteered to participate. Throwing arm dominance was not a factor contributing to participant selection or exclusion. The University's Institutional Review Board (IRB) approved all testing protocols. Informed consent was obtained from participants and the rights of the participants were protected according to the guidelines of the IRB.

Participants reported for testing prior to engaging in resistance training or any vigorous activity that day. Kinematic data were collected using The MotionMonitor™ motion capture

system (Innovative Sports Training, Chicago, IL). Participants had a series of 1 electromagnetic sensors (Flock of Birds Ascension Technologies Inc., Burlington, VT) attached at the following locations: (1) medial aspect of c7; (2) medial aspect of pelvis at S1; (3) distal/posterior aspect of throwing humerus; (4) distal/posterior aspect of throwing forearm; (5-6) bilateral distal/posterior aspect of upper leg; (7-8) bilateral distal/posterior aspect of lower leg; (9-10) bilateral proximal dorsum of foot. Sensors were affixed to the skin using double-sided tape and then wrapped using flexible hypoallergenic athletic tape to ensure proper placement. Sensors were placed over areas with the least muscle mass in attempt to minimize sensor movement. Following sensor assignment placement, a 11th sensor was attached to a wooden stylus and used to digitize the palpated positions of the body landmarks. (Wu, Siegler, Allard, Kirtley, Leardini, Rosenbaum, Whittle, D'Lima, Cristofolini, Witte, Schmid, & Stokes, 2002; Myers, Laudner, Pasquals, Bradley, Lephard, 2005; Oliver, Plummer, 2011). Participants were instructed to stand in anatomical neutral while selected body landmarks were accurately digitized. The coordinate systems used were in accordance with the International Shoulder Group of the International Society of Biomechanics Recommendations (Wu et al., 2002). Data describing the position and orientation of electromagnetic sensors were collected at 100 Hz. Raw data were independently filtered along each global axis using a 4th order Butterworth filter with a cutoff frequency of 13.4 Hz (Fleisig, Barrentine, Zheng, Escamilla, & Andrews, 1999). Two points described the longitudinal axis of the segment and the third point defined the plane of the segment. A second axis was defined perpendicular to the plane and the third axis was defined as perpendicular to the first and second axes. Neutral stance was the y-axis in the vertical direction, horizontal and to the right of y was the x-axis, and posterior was the z-axis. Euler angle decompositions were used to determine humeral orientations.
Following set-up, participants performed their normal warm-up routine. Those data from the fastest throw were selected for detailed analysis (Rojas et al., 2009; Oliver & Keeley, 2010a,b). The throwing surface was constructed so that the participant's stride foot would land on top of a 40 x 60 cm Bertec force plate (Bertec Corp, Columbus, Ohio) set into the floor. Participants' throwing speed was determined by a JUGS radar gun (OpticsPlanet, Inc., Northbrook, IL) positioned in the direction of the throw. Relevant kinematic and kinetic variables were compared among the three positions using a one-way ANOVA ($p<0.05$).

RESULTS: Participants were approximately the same age (19.2 ±1.0 y) and mass (68.9 ±8.7 kg) and height (168.6 ±6.6 cm). Kinematics and kinetic data for participants are broken down by throwing event (foot contact, maximum external rotation, ball release, and maximum internal rotation) are presented in Tables 1-4. Of all the kinematic and kinetic variables, there where no significant differences between different position players and the throwing events. There was a significant difference in the catcher's shoulder plane of elevation when compared to the other two position players when examining the entire throw ($p=0.03$).

Table 1: Kinematics & kinetics: foot contact.

Variable	Infielders (n=8)	Catchers (n=4)	Outfielders (n=6)
Shoulder Moment [Nm]	11 ±5	7 ±4	15 ±8
Elbow Moment [Nm]	3 ±1	3 ±1	3 ±2
Shoulder Plane of Elevation [°]	22 ±15	8 ±6	26 ±14
Shoulder Rotation [°]	83 ±60	23 ±13	67 ±3
Elbow Flexion [°]	92 ±22	120 ±4	101 ±15
Hip Speed [°/s]	153 ±93	135 ±95	115 ±6
Trunk Speed [°/s]	121 ±63	139 ±56	213 ±33
Upper Arm Speed [°/s]	416 ±120	162 ±66	341 ±6
Lower Arm Speed [°/s]	697 ±240	289 ±131	679 ±177

Table 2: Kinematics & kinetics: maximum shoulder external rotation.

Variable	Infielders (n=8)	Catchers (n=4)	Outfielders (n=6)
Shoulder Moment [Nm]	45 ±11	41 ±17	43 ±11
Elbow Moment [Nm]	3 ±1	3 ±2	3 ±2
Shoulder Plane of Elevation [°]	15 ±12	31 ±4	13 ±6
Shoulder Rotation [°]	94 ±14	88 ±15	70 ±23
Elbow Flexion [°]	91 ±22	93 ±17	90 ±4
Hip Speed [°/s]	481 ±72	356 ±114	421 ±17
Trunk Speed [°/s]	796 ±112	809 ±84	826 ±220
Upper Arm Speed [°/s]	1084 ±277	925 ±170	1227 ±163
Lower Arm Speed [°/s]	1347 ±125	1382 +351	1547 ±113

Table 3: Kinematics & kinetics: ball release.

Variable	Infielders (n=8)	Catchers (n=4)	Outfielders (n=6)
Shoulder Moment [Nm]	53 ±19	62 ±16	46 ±23
Elbow Moment [Nm]	21 +11	14 ±4	16 ±10
Shoulder Plane of Elevation [°]	19 ±12	37 ±3	17 ±7
Shoulder Rotation [°]	89 ±34	51 ±4	56 ±17
Elbow Flexion [°]	57 ±15	30 ±23	57 ±27
Hip Speed [°/s]	158 ±72	188 ±190	87 ±84
Trunk Speed [°/s]	439 ±90	368 ±65	382 ±171
Upper Arm Speed [°/s]	1572 +416	1850 ±425	1452 ±353
Lower Arm Speed [°/s]	2384+388	2726 ±132	2900 ±195

Table 4: Kinematics & kinetics: maximum shoulder internal rotation.

Variable	Infielders (n=8)	Catchers (n=4)	Outfielders (n=6)
Shoulder Moment [Nm]	70 ±34	64 ±18	49 ±23
Elbow Moment [Nm]	10 ±6	7 ±2	8 ±2
Shoulder Plane of Elevation [°]	45 ±12	69 ±16	48 ±2
Shoulder Rotation [°]	80 ±72	19 ±9	24 ±13
Elbow Flexion [°]	29 ±14	22 ±17	30 ±2
Hip Speed [°/s]	142 ±64	103 ±29	235 ±100
Trunk Speed [°/s]	210 ±100	222 ±159	335 ±60
Upper Arm Speed [°/s]	1374 ±358	1159 ±293	1086 ±38
Lower Arm Speed [°/s]	1206 ±391	1012 ±338	924 ±25

DISCUSSION: The purpose of this study was to thoroughly describe the biomechanics of the throwing motion of collegiate softball position players. Such information allows for a comprehensive understanding for development and training for positional players. The results of this study revealed that there were no significant differences between the positional players when examining the different throwing events. However when examining the overall throw, catchers displayed significantly different plane of shoulder elevation (horizontal abduction).

At the point of MER shoulder and elbow moments were similar with the infielders displaying greater shoulder moments, shoulder external rotation, and hip speed. While outfielders' exhibited greater mean lower arm speed at ball release possibly as a result of the distance that their position requires them to throw.

At BR and MIR, the catchers displayed the greatest shoulder moments when compared to the infielders and outfielders as well as compared to the pitchers previously examined (Werner et al. 2006). In addition, the catchers displayed immediate elbow flexion and maintained the greatest elbow flexion and plane of elevation as compared to the other positional players throughout ball release.

CONCLUSION: This study identified the throwing mechanics of positional players actively competing in collegiate softball. Though there were no significant differences in the throwing motion of softball position players when examining the different throwing events, a difference was revealed in the overall throwing motion. It should be noted that this study was limited in the lack low numbers and the low statistical power. Therefore it is proposed to conduct similar studies with greater numbers in addition to increasing the power and thoroughly understand the throwing mechanics of softball positional players.

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