QUANTITATIVE ANALYSIS OF SLIDE STEP DELIVERY IN HIGH SCHOOL BASEBALL PITCHERS

Jonathan Parker[1], Jessica Cohen[1], and Gretchen Oliver[1]

[1]Department of Health, Human Performance, and Recreation, University of Arkansas, Fayetteville, USA[1]

The purpose of this study was to quantify the kinetics, kinematics, and segmental sequentiallity during the slide step pitching motion in high school baseball pitchers. Eighteen participants [16.2 ± 1.6 yrs; 76.9 ± 12.2 kg; 178.2 ± 7.2 cm] volunteered to participate. Kinematic data describing the kinematics and kinetics during the slide step pitching delivery were collected with an electromagnetic tracking system via the MotionMonitor™ and calculated as per ISB recommendations. Data were described at foot contact, maximum external shoulder rotation, ball release, and maximum internal shoulder rotation during the slide step delivery.

KEY WORDS: kinetic chain; motion analysis; pitching delivery styles.

INTRODUCTION: The overhand throw is considered a dynamic movement that involves not only skill but the proper coordination of all body segments. Throughout the sequential movement pattern it is assumed that the lower extremity and trunk musculature must be activated before the arm motion occurs in attempt to produce normal upper extremity motor patterns utilized during pitching. Within the pitching motion, as the pitch cycle progresses, the proximal segments of the legs and trunk work sequentially in effort to accelerate the shoulder for optimal force production [Pappas, Zawacki, Sullivan, 1985]. Achievement of maximum external shoulder rotation during baseball pitching is dependent on the sequential functioning of the hips, pelvis, torso, and scapula. The large muscles of the hip and trunk help position the thoracic spine to accommodate for motions of the scapula in attempt to allow for full functional shoulder motion. Much of the previous baseball literature has been based on the sequential activation of the kinetic chain while pitching from the wind-up [Fleisig, Kingsley, Loftice, et al., 2006; Werner, Gill, Murray, et al., 2001] There is limited data describing the stretch delivery of performing the high leg kick or the slide step [Dun, Kingsley, Fleisig, et al., 2008]. When utilizing the slide step delivery, the pitcher's trunk is perpendicular to home plate and the high leg kick is all but eliminated. Pitchers most often pitch from the stretch when they are trying to hold a runner on first. When throwing from the stretch and using the slide step delivery, the pitcher has the ability to produce a quicker delivery of the ball to home plate which limits the amount of time the base runner has to steal.

It has been reported that advanced players are consistent in their kinematics and kinetic when throwing from the stretch delivery [Dun, Kingsley, Fleisig, et al., 2008]. However, there has been no known investigation into the mechanical consistency of young pitchers while performing a throw from the slide step delivery. Therefore, it was the objective of this study to quantify the kinetics, kinematics, and segmental sequentiallity during the slide step pitching motion in high school baseball pitchers. It was hypothesized that the kinetics and kinematics would be similar to those high school data previously reported, as well as there would be a definite proximal to distal sequential sequencing of segments.

METHOD: A controlled laboratory study design was implemented for the current study. Eighteen high school male baseball 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 approved all testing protocols used in the current study, and prior to participation the approved procedures, risks, and benefits were explained to all participants. Informed consent was obtained from participants and the rights of the participants were protected according to the guidelines of the University's Institutional Review Board.

Participants reported for testing prior to engaging in resistance training or any vigorous activity that day. Kinematic data were collected using The MotionMonitor^{TM} motion capture system [Innovative Sports Training, Chicago, IL]. Participants had a series of 10 electromagnetic sensors [Flock of Birds Ascension Technologies Inc., Burlington, VT] attached at the following locations: [1] midline of c7; [2] midline of pelvis at S1; [3] distal/posterior one-third of throwing humerus; [4] distal/posterior one-third of throwing forearm; [5-6] bilateral distal/posterior one-third of upper leg; [7-8] bilateral distal/posterior one-third 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. Following the attachment of the electromagnetic sensors, an 11th sensor was attached to a wooden stylus and used to digitize the palpated positions of the body landmarks. [Myers, Laudner, Pasquals, Bradley, Lephard, 2005; Oliver, Plummer, 2011; Wu, Siegler, Allard, et al., 2002]. Participants were instructed to stand in anatomical neutral while selected bony landmarks were accurately digitized. The coordinate systems used were in accordance with the International Shoulder Group of the International Society of Biomechanics Recommendations [Wu, Siegler, Allard, et al., 2002]. 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.
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). Euler angle decompositions were used to determine humeral orientations. Humeral orientation was the rotation about the y-axis as the plane of elevation, rotation about the z-axis as elevation, and rotation about the y-axis as axial rotation.
Following set-up, participants were allotted an unlimited time to perform their own specified pre-competition warm-up routine. After completing their warm-up and gaining familiarity with the pitching surface, they were instructed to throw five fastballs for strikes using the slide step delivery to a catcher located regulation distance [18.44 m] at home plate. The mound was positioned so that the participant's 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. Those data from the fastest throw passing through the strike zone were selected for analysis [Oliver, Keeley, 2010a; Oliver, Keeley, 2010b]. Data were analyzed in the current study using the statistical analysis package SPSS 19.0 for Windows. Descriptive statistics means and standard deviations, for all data were calculated.
RESULTS: Participants were approximately the same age [16.2 ± 1.6 yrs] and mass [76.9 ± 12.2 kg] and height [178.2 ± 7.2 cm]. Kinematics and kinetic data are divided by event [foot contact (FC), maximum external rotation (MER), ball release (BR), and maximum internal rotation (MIR)] are presented in Tables 1-4. Segmental speeds are presented in Figure 1.

Table 1: Kinematics & kinetics: foot contact.

Variable	Mean ± SD
Shoulder Moment [Nm]	14 ± 8
Elbow Moment [Nm]	6 ± 6
Shoulder Plane of Elevation [°]	111 ± 27
Shoulder Elevation [°]	86 ± 31
Shoulder Rotation [°]	66 ± 54
Elbow Flexion [°]	73 ± 30

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

Variable	Mean + SD
Shoulder Moment [Nm]	63 + 56
Elbow Moment [Nm]	19 + 10
Shoulder Plane of Elevation [°]	87 + 32
Shoulder Elevation [°]	92 + 34
Shoulder Rotation [°]	103 + 25
Elbow Flexion [°]	77 + 25

Table 3: Kinematics & kinetics: ball release.

Variable	Mean + SD
Shoulder Moment [Nm]	48 + 32
Elbow Moment [Nm]	29 + 27
Shoulder Plane of Elevation [°]	79 + 26
Shoulder Elevation [°]	93 + 34
Shoulder Rotation [°]	82 + 41
Elbow Flexion [°]	40 + 26

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

Variable	Mean + SD
Shoulder Moment [Nm]	72 + 46
Elbow Moment [Nm]	13 + 11
Shoulder Plane of Elevation [°]	48 + 36
Shoulder Elevation [°]	83 + 29
Shoulder Rotation [°]	60 + 56
Elbow Flexion [°]	31 + 32

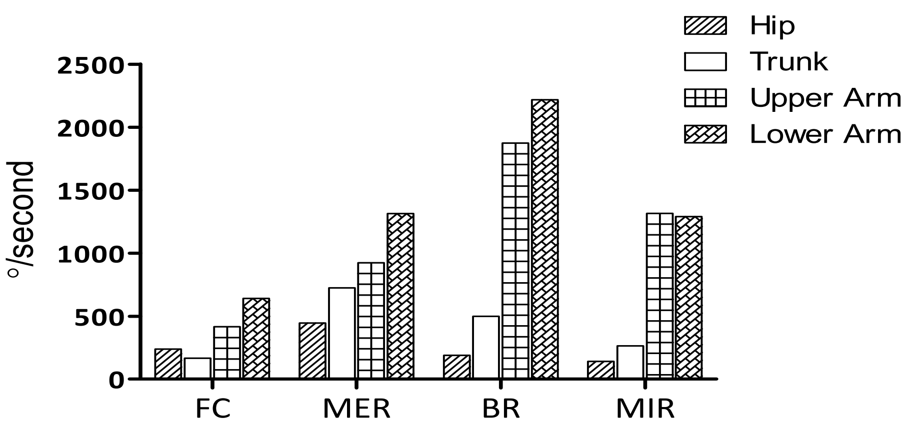

Figure 1. Segmental speed expressed by degrees per second at each event durign the throwing motion.

DISCUSSION: The purpose of this study was to thoroughly describe the biomechanics of the throwing motion of the slide step baseball pitching motion. The movement was broken down into four events of FC, MER, BR, and MIR. Analysis of the events allows for better understanding of the sequentiallity of the movement in this study group.

During FC the hips and trunk did not display a sequential sequencing in angular velocity, as seen in previous reports [Dun, Loftice, Fleisig, et al., 2008]. The point of MER displayed less elbow flexion than previously reported [Dun, Loftice, Fleisig, et al., 2008]. The decreased elbow flexion could be a compensatory mechanism of the altered sequentiality displayed in FC. In addition, the shoulder moment of the participants were greater than previously described in youth pitchers. At BR shoulder plane of elevation [shoulder abduction], and elbow and shoulder moments were higher than previously reported [Dun, Loftice, Fleisig, et al., 2008]. Then at MIR the current data revealed a lack of sequentiality of the upper and lower arm segments. Of the data presented and those previously documented, it should be noted that the current data reported the mean value while the previously reported data reported the maximum value.

CONCLUSION: This study identified the throwing mechanics of high school baseball pitchers performing the slide step delivery in baseball pitching. In this study it was found that high school baseball pitchers experience flaws in the sequential angular velocities during foot contact and maximum internal rotation. It was also identified that the force moments on the shoulder and elbow where higher than previous research at maximum external rotation and ball release. This may indicate a flaw in the mechanics of young pitchers during the slide step pitch. The flaws in the mechanics may lead to further injury if not corrected. Therefore, it is suggested focus on proper mechanics of the overhand baseball throw before advancing to the slide step.

REFERENCES:

Dun, S., Kingsley, D., Fleisig, G.S., et al. (2008). Biomechanical comparison of the fastball from wind-up and the fastball from stretch in professional baseball pitchers. *American Journal of Sports Medicine*,36:137-141.

Dun, S., Loftice, J.W., Fleisig, G.S., et al. (2008). A biomechanical compairson of youth baseball pitchers. Is the curveball potentially harmful? *American Journal of Sports* Medicine, 36(4): 686-692.

Fleisig, G.S., Barrentine, S.W., Zheng, N., Escamilla, R.F., & Andrews, J.R. (1999). Kinematic and kinetic comparison of baseball pitching among various levels of development. *Journal of Biomechanics, 32*, 1371-1375.

Fleisig, G.S., Kingsley, D.S., Loftice, J.W., et al. (2006). Kinetic comparison among the fastball, curveball, change-up, and slider in collegiate baseball pitchers. *American Journal of Sports Medicine,* 34(3):423-430.

Myers, J.B., Laudner, K.G., Pasquale, M.R., Bradley, J.P., & Lephart, S.M. (2005). Scapular position and orientation in throwing athletes. *American Journal of Sports Medicine,* 33, 263-271.

Oliver, G.D., Keeley, D.W. (2010a). Gluteal muscle group activation and its relationship with pelvic and trunk kinematics in high school baseball pitchers. *Journal of Strength and Conditioning Research,* 24, 3015-3022.

Oliver, G.D., Keeley, D.W. (2010b). Pelvic and trunk kinematics and their relationship to shoulder kinematics in high school baseball pitchers. *Journal of Strength and Conditioning Research,* 24, 3234-3240.

Pappas AM, Zawacki RM, Sullivan TJ. Biomechanics of baseball pitching. A preliminary report. *American Journal of Sports Medicine,* 1985 13:216-222.

Wu, G., Siegler, S., Allard, P., et al. (2002). ISB recommendation on definitions of joint coordinate system of various joints for the reporting of human motion – part I: Ankle, hip, and spine. *Journal of Biomechanics,* 35, 543–548.

Werner, S.L., Gill, T.J., Murray, T.A., et al. (2001). Relationships between throwing mechanics and shoulder distraction in professional baseball pitchers. *American Journal of Sports Medicine,* 29(3):354-358.

Acknowledgement: The authors would like to thank the University of Arkansas Sport Biomechanics Group for their assistance in data collection.