DIFFERENCES IN ANGULAR VELOCITY AMONG SELECTED KINEMATICS DURING A LEFT-HANDED PITCHER'S PICK-OFF MOVE

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Previous research on the left-handed pitcher's pick-off move has only focused on angular displacements. The purpose of this study was to analyze differences in angular velocity among selected kinematic variables between a pick-off move to first base and a normal delivery to home plate. Kinematic data were collected on pitchers (n=10) performing deliveries to first and home. Significant differences existed in nearly all of the kinematic variables. The timing of these differences can be used to aid baserunners in determining at which angles and at what times they should focus their attention.

KEY WORDS: baseball, pick-off, left-handed, pitching.

INTRODUCTION: When a baseball pitcher delivers the ball from the set position to a base instead of home plate, this is known as the pick-off move. It is an essential skill for any baseball pitcher. Coaches agree that the importance of the pick-off to first base is magnified for left-handed pitchers (LHPs) because they face first base as they wind up and can make their move later and more deceptively (Mazzoni, 1995; Stallings, 1997). With this in mind, LHPs are encouraged to maximize this advantage in order to control baserunners and prevent them from advancing to second base. The most common LHP pick-off move to first base is the 45° or "balk" move. In this move, the pitcher mimics his delivery to home plate for as long as he can and attempts to land on or near the imaginary line bisecting the 90° angle between home plate and first base. A "balk" is any illegal action taken by a pitcher, such as stepping on the wrong side of this imaginary line to intentionally deceive the baserunner. Most coaches have similar philosophies when it comes to teaching this highly skilled move. Principles such as maintaining equal lower body movements and rhythms during deliveries to home and first, not pointing lead leg or toe to first unless it is a part of both motions to home and first, and avoiding conspicuous shoulder, torso, and hip rotation are professed to LHPs (Mazzoni, 1995). Despite an abundance of research in the area of the biomechanics of baseball pitching (Elliot, Grove, & Gibson, 1985; Pappas, Zawacki, & Sullivan, 1985; Barrentine, Matsuo, Escamilla, Fleisig, & Andrews, 1998; Dillman, Fleisig, & Andrews, 1993; Feltner & Dapena, 1986; Werner, Fleisig, Dillman, & Andrews, 1993; Hong & Roberts, 1993; Stodden, Fleisig, McLean, Lyman, & Andrews, 2001), a dearth of literature on the biomechanics of the pick-off exists. Only one study (Fortenbaugh & Butcher-Mokha, 2004) analyzed the LHP pick-off move to first base, finding approximately a 40° difference in upper torso rotation between the deliveries. Insight into the pick-off move would be valuable for LHPs and baserunners alike; LHPs would learn how to improve their mechanics to mask differences between the two delivery types, and baserunners would learn LHPs' weaknesses and how to exploit them. Therefore, the purpose of this study was to provide a more comprehensive description of the pick-off move and how it varies from a normal delivery to home plate in collegiate LHPs. In accordance with this purpose, angular velocities of selected joint angles were compared between deliveries to home plate and first base. It was hypothesized that differences would exist between the throws because the targets of the two throws are at right angles to each other, making it impossible for the deliveries to be identical. A second hypothesis was that the changes would occur near the end of the delivery because LHPs would try to cloak their differences for as long as they could.

METHOD:

Data Collection: Ten healthy LHPs from National Collegiate Athletic Association (NCAA) Division I and II and National Association of Intercollegiate Athletics (NAIA) schools were recruited for this study. All pitchers had previous college experience and were free of

orthopedic injury for at least 9 months. Four 60 Hz JVC cameras were placed in the corners of the Barry University Biomechanics Laboratory facing the center where the participant performed the trials. Prior to collection, a 2 x 2 x 2 m control object containing 21 points with known coordinates was videotaped for calibration purposes. Testing for both deliveries occurred on the same day, and the cameras remained stationary. After reading and signing the informed consent form, participants were given time to familiarize themselves with the laboratory setting and were instructed as to the virtual locations of the mound, home plate, and first base. Participants then performed a warm-up session consisting of 10 minutes of stretching and 5-10 "dry" repetitions of both deliveries. Reflective markers were then placed bilaterally on the acromions, lateral epicondyles, greater trochanters, lateral femoral condyles, lateral malleoli, and on the shoes over the 5th metatarsals. To create the most game-like atmosphere, pitchers wore their baseball mitts and threw a ball constructed of athletic tape with same size and mass of a real baseball. This replacement ball was used for the safety of both the pitcher and the laboratory. Participants were instructed to "throw with game-like intensity" toward the direction of home plate and first base in a pre-determined, yet randomized order. With 15-20 seconds of rest between each trial, the pitcher completed the deliveries for a total of eight trials, four in each direction. One trial from each delivery, the self-reported "best" trial according to each LHP was selected for analysis. The images were digitized and analyzed from the 10th frame before the initial left leg lift through the 10th frame after the leg touched down using Peak Motus Ver. 8.2 software (Peak Performance Technologies, Inc., Centennial, CO). Three-dimensional coordinates were obtained using the Direct Linear Transformation (DLT) method (Abdel-Aziz & Karara, 1971). The transformed coordinates were smoothed using a Butterworth filter (10 Hz cut-off frequency).

Data Analysis: Seven lower body angles (right and left ankle flexion (RAF, LAF), right and left knee flexion (RKF, LKF), right hip flexion (RHF), right hip rotation (RHR) measured by shank movement of the flexed leg, and right hip transverse abduction (RHTA)) and three upper body angles (right and left shoulder abduction (RSA, LSA) and upper torso rotation (UTR)) were measured. Four phases of the pick-off delivery were also defined by three events and subsequently used as references. The three events were: the top of the leg kick (x-intercept of RHF velocity, going positive to negative); the push-off of the left leg to drive the body in its intended throwing direction (x-intercept of the LAF velocity, going negative to positive); and the final clockwise rotational thrust of the torso (x-intercept of the UTR velocity, going negative to positive). No portable mounds were used and a limited pitching space was available, but this study effectively compared LHPs to themselves, so commensurate effort and conditions were assumed to exist for both delivery types. A repeated measures MANOVA design compared angular velocities of the measured variables in certain phases between delivery types. Significance was set at $\alpha = 0.01$. Two inclusion criteria were used for data selection: first, only relative maximums of angular velocity were used; and second, only instances in which all ten participants reached a relative maximum at approximately the same percent time of that phase were used. When the body is in motion, joint angles alternate between two directions in a given plane (e.g. elbow flexion and extension in the sagittal plane), and relative maximums in angular velocity refer to any point when the speed of the angle, moving in one of the two directions, increased, peaked, and subsequently decreased. The peak value was the value recorded for measurement. The total elapsed time, irrespective of delivery type, was used because a baserunner would not know if he had just watched, say, 0.75 s of a pick-off delivery to first or 0.75 s of a delivery to home plate. The percent time of the phase was used to ensure that the same part of each pitcher's delivery was being compared, regardless of the total delivery time. Finally, angular velocity was compared because Morrison et. al. (2005) concluded that visual estimates of angular velocity are much more accurate than visual estimates of angular displacement.

RESULTS: The performances of the LHPs are summarized in Table 1. There were 16 occurrences among the 10 dependent variables during the 4 phases that met the inclusion criteria. Each occurrence is listed along with the phase and means and SDs for absolute time, percent time of the phase, angular velocity of delivery to first base, and angular velocity of delivery to home plate. The last column represents the absolute value difference between the angular velocities of deliveries to home plate and first base.

Table 1. Performance of LHPs.

Measure	Phase	Time (s)	Phase Time (%)	Angular Velocity to First (deg/s)	Angular Velocity to Home (deg/s)	Abs. Mean Diff.
RAF	I	0.19 ± 0.09	29.4 ± 8.4	195.3 ± 64.1	113.9 ± 64.2	81.4*
RAF	II	0.81 ± 0.18	21.9 ± 17.6	50.2 ± 42.6	-1.8 ± 37.3	52.0*
LAF	II	0.98 ± 0.17	61.7 ± 15.2	-41.6 ± 22.2	-10.8 ± 11.2	30.8*
RKF	I	0.64 ± 0.09	94.6 ± 14.1	87.9 ± 66.0	146.7 ± 91.2	58.8*
RKF	II	1.08 ± 0.17	82.5 ± 15.0	-186.4 ± 46.8	-96.3 ± 57.1	90.1*
LKF	I	0.50 ± 0.14	71.6 ± 15.2	28.2 ± 13.7	8.2 ± 11.8	20.0*
RHF	I	0.46 ± 0.17	65.0 ± 14.8	230.0 ± 43.8	185.2 ± 41.2	44.8*
RHF	II	0.87 ± 0.14	37.3 ± 13.2	-255.4 ± 39.5	-155.5 ± 99.9	99.9*
RHR	I	0.39 ± 0.14	57.1 ± 18.4	68.8 ± 22.7	31.7 ± 22.6	37.1*
RHR	II	0.93 ± 0.19	49.6 ± 21.0	-58.5 ± 31.2	-26.8 ± 30.7	31.7*
RSA	III	1.31 ± 0.21	60.6 ± 33.3	233.0 ± 130.5	97.4 ± 90.6	135.6*
LSA	II	1.04 ± 0.19	75.8 ± 18.7	62.0 ± 29.7	24.3 ± 28.0	37.7*
LSA	III	1.39 ± 0.26	89.2 ± 29.2	959.3 ± 770.7	-181.8 ± 139.7	1141.1*
UTR	II	1.10 ± 0.23	83.1 ± 17.1	114.0 ± 54.0	13.7 ± 20.7	100.3*
RHTA	I	0.15 ± 0.06	21.9 ± 9.7	-180.5 ± 152.1	-303.6 ± 289.4	123.1
RHTA	III	1.31 ± 0.24	46.1 ± 36.9	108.9 ± 67.3	293.2 ± 71.5	184.3*

Note: * denotes significant difference between deliveries, p<.01.

DISCUSSION: It was hypothesized that, based on physical capabilities, there were innate differences between deliveries to first base and home plate, and this hypothesis was supported with significant findings in 15 of 16 kinematic variables. The differences can be separated into groups: internal and external. Internal differences are those that occur due to the pitcher's inability to perfectly mimic his delivery to home plate with his pick-off move. External differences are those that occur due to the inevitability of the two deliveries being fundamentally different. It is debatable into which category some of the variables measured in this study fall. Based on qualitative assessments of the motions, it is theorized that among these variables, differences in LAF(Phase II), LKF(I), LSA(II), LSA(III), UTR(II), and RHTA(III) can be seen as external, while the others can be labeled as internal differences. Many of these external differences do not occur until later in the motion (i.e., Phase III) because LHPs have excelled in masking their differences for as long as they could before revealing them in order to deliver the ball to first base, supporting the second hypothesis of this study. Another way to classify these variables is as those that have and those that do not have practical significance. Some mean differences were between 30 and 50 deg/s, while others were upwards of 200 deg/s, with one difference over 1100 deg/s. No known study has ever proposed a threshold value for a detectable difference in angular velocity when comparing two motions, so it is still unknown how large a difference is needed so that it would be noticeable. Based on Morrison et. al. (2005), which only analyzed elbow flexion, one might conclude that the differences found in this study are large enough to be observed by a baserunner, but this is a vague conclusion at best. In addition, watching multiple body segments in a complex motion like a pitcher's delivery may alter a baserunner's ability to effectively observe any differences. Knowing which body segments to observe and at which point of a phase may further improve the baserunners' discriminatory abilities.

CONCLUSION: Based on the results of this study, it can be concluded that differences do exist between deliveries to first base and home plate. Furthermore, with the timing of these differences as it is, baserunners interested in attempting to discriminate LHP delivery types in an effort to steal second base are advised to wait to make a decision, while LHPs are exhorted to conceal these differences for as long as possible.

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