A KINEMATIC COMPARISON OF THE DELIVERY MOTIONS OF CATCHERS AND INFIELDERS IN BASEBALL

Tomohisa Miyanishi and So Endo

Graduate School of Sports Science, Sendai University, Miyagi, Japan

The aim of this study was to compare the delivery motions of baseball catchers and infielders. Thirteen catchers and 16 infielders participated in the study. 3D analysis was used to analyze the release parameters, the durations of 4 phases, and trunk, pelvis and throwing arm kinematics in the two groups. No statistical difference in ball velocity and angle of release was found between the groups. Of the 45 angular position and angular velocity parameters tested at key instants in the throws, 15 showed significant differences between the groups. The only significant differences in maximum angular velocities and in their times of occurrence were in the maximum pelvis forward rotation angular velocity and in the time of occurrence of the maximum elbow extension angular velocity. These results should be useful for the improvement of baseball throwing motions.

KEY WORDS: throw, skilled thrower, trunk and throwing arm, 3D motion picture analysis

INTRODUCTION: There are differences between the techniques of baseball players who play in different positions. Even though the purpose of the throws of all position players is the same, a combination of maximum velocity and precision, the throwing motions of the various position players should be expected to be different due to differences in the physical conditions, for example the presence or absence of a pitching mound, the distance between thrower and target, the presence or absence of an approach run (spatial restrictions), or the need to throw quickly or not (temporal restriction). If the differences between the delivery motions of the various position players were better known, this information could be used to improve the delivery motions of the various position players.

Most previous studies on the baseball throwing motion have concentrated on pitching (Feltner & Dapena, 1986; Sakurai, Ikegami, Okamoto, Yabe & Toyoshima, 1993; Fleisig, Barrentine, Zheng, Escamilla & Andrew, 1999; Matsuo, Escamilla, Fleisig, Barrentine & Andrew, 2001; Stodden, Fleisig, McLearn, Lyman & Andrew, 2001). We know of no studies that deal with the delivery motions of position players, except for the previous study reported by Miyanishi & Sakurai (2011), who investigated the linear and angular contributions to ball velocity in the delivery motions of infielders at various levels of development. The purpose of the present study was to compare the delivery motions of the catcher (CA) and infielder (IN) in baseball.

METHODS: Thirteen catchers (age 19.7±0.9 yrs, standing height 1.74±0.04 m, body mass 72.5±5.2 kg, throwing experience 11.7±2.3 yrs) and 16 infielders (age 19.8±0.8 yrs, standing height 1.72±0.04 m, body mass 68.8±5.7 kg, throwing experience 10.6±1.9 yrs) participated in this study. They were all healthy, and had no history of arm surgery nor arm pain at present. Informed written consent was obtained from all participants.

Each catcher was requested to catch a ball directly thrown by a person in front of home plate, and then deliver the ball as quickly and accurately as possible with maximum effort toward a target (width: 1.4 m; height: 1.7 m) set up at second base, 40 m away. Each infielder was requested to catch a ground ball rolled by a person in front of the shortstop fielding position, and then deliver the ball as quickly and accurately as possible with maximum effort toward the same target set up at first base, 35 m away. Figures 1a and 1b show typical sequences of the delivery motions of catchers and infielders, respectively. The throws were recorded using two high-speed genlocked video cameras (HSV-500C^3, NAC, Japan) at a frame rate of 250 Hz.

For each thrower, a single trial in which the ball hit the target was selected for subsequent analysis. The positions of 25 body landmarks and of the ball center were manually digitized in the video images using a Video Motion Analysis System (Frame-DIAS, DKH, Japan). The three-dimensional (3D) coordinates of the body landmarks and of the ball center were reconstructed using the Direct Linear Transformation (DLT) method (Abdel-Aziz & Karara, 1971; Walton, 1981), and then smoothed using quintic spline functions (Woltring, 1986) with optimal cutoff frequencies determined for each landmark coordinate according to Winter (1990). The body segment parameters needed for calculation of the body center of mass (CM) were obtained from the standing height and body mass of each thrower using de Leva's (1996) adjustments of the values reported by Zatsiorsky, Seluyanov & Chugunova (1990).

The delivery motion was divided into 4 phases based on 5 instants (catching the ball, CAT; pivot foot contact, PFC; stride foot contact, SFC; maximum external rotation of shoulder, MER; and ball release, REL) as follows: step, stride, arm cocking, and arm acceleration (Figure 1).

Kinematic parameters were calculated based on the previous study of Miyanishi, Sakurai & Endo (2015) as follows: ball velocity, angle of release, and height of release (expressed as a percentage of standing height, %SH); durations of the entire delivery and of its 4 phases; height of body CM (%SH) at PFC, SFC and REL; stride length from PFC to SFC (%SH); 12 angular position parameters including the throwing shoulder and elbow joints, trunk, pelvis and stride knee joint at PFC, SFC and REL; 6 ranges of motion of the upper trunk and pelvis from PFC to REL; 3 angular velocity parameters at REL, including the throwing shoulder and elbow joints; 4 maximum values of angles of shoulder, elbow and trunk and their times of occurrence (%Throw); and 6 maximum angular velocity parameters, including the throwing shoulder and elbow joints, trunk and pelvis, and their times of occurrence (%Throw).

Student t-tests were performed using SPSS version 20 (SPSS Inc., Chicago, IL) to assess the differences in all calculated parameters between the two groups. Significance levels were set at $p < .05$ for each test.

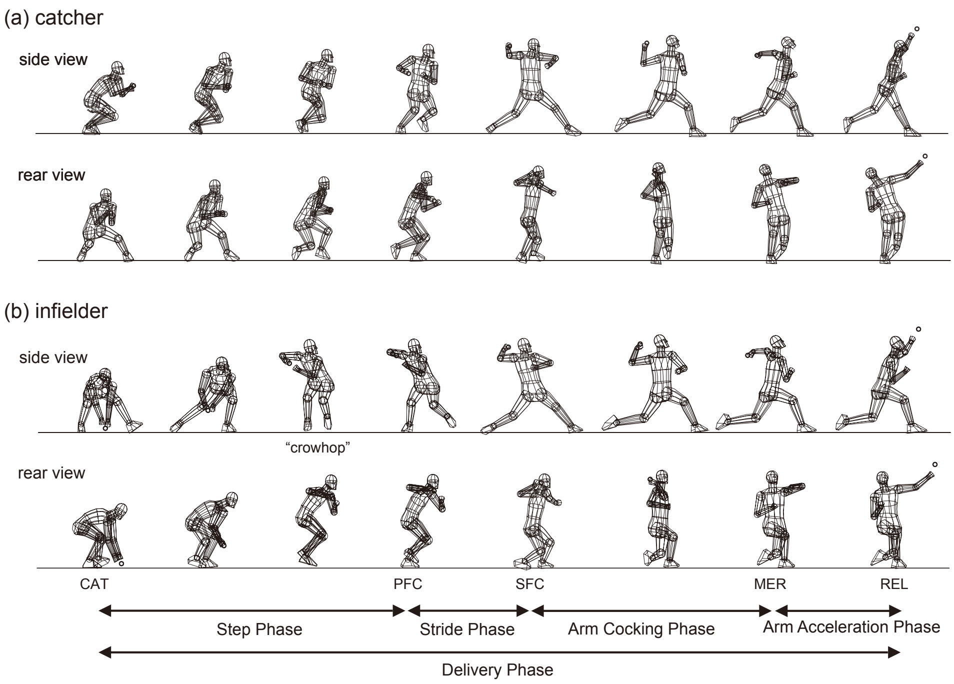

Figure 1: Typical sequences of the delivery motion of (a) catcher and (b) infielder, and definitions of the four phases. (See main text.)

RESULTS: No statistical differences were found in age, standing height (SH), body mass and throwing experience between the two groups. No significant differences in the ball velocity (CA 33.1±1.4 m/s; IN 33.2±1.5 m/s) and angle of release (CA 8.2±1.6°; IN 7.3±1.4°) were found between the two groups, while the release height was significantly larger in catchers than in infielders (CA 94.9±4.9%; IN 83.8±3.5%, $p < .01$). No significant differences were found in the duration of the entire delivery (CA 0.727±0.059 s; IN 0.778±0.080 s). The step phase was significantly shorter in catchers than in infielders (CA 0.301±0.082 s; IN 0.425±0.034 s, $p < .001$). The stride phase was significantly longer in catchers than in infielders (CA 0.253±0.077 s; IN 0.176±0.061 s, $p < .01$). No significant differences were found in the durations of the phases of arm cocking (CA 0.137±0.028 s; IN 0.140±0.017 s) and arm acceleration (CA 0.037±0.004 s; IN 0.037±0.005 s). The body CM height was significantly larger in catchers than in infielders at SFC (CA 44±2%; IN 42±1%, $p < .05$), but not significantly different at PFC and REL.

Table 1: Significantly different angular parameter values

	Catcher (CA)	**Infielder (IN)**	sig.diffs
At instant of pivot foot contact [PFC]			
Shoulder abduction (°)	40 ± 25	63 ± 15	*
Shoulder horizontal adduction (°)	40 ± 22	10 ± 20	**
Upper trunk rightward tilt (°)	-31 ± 10	-43 ± 8	**
Pelvis rightward tilt (°)	-31 ± 4	-17 ± 5	**
Pelvis backward rotation (°)	-79 ± 16	-93 ± 11	**
Stride knee extension (°)	87 ± 12	76 ± 13	*
At instant of stride foot contact [SFC]			
Shoulder external rotation (°)	70 ± 25	49 ± 22	*
At instant of ball release [REL]			
Shoulder horizontal adduction (°)	13 ± 6	1 ± 7	***
Shoulder external rotation (°)	120 ± 12	106 ± 17	*
Upper trunk leftward tilt (°)	19 ± 6	13 ± 6	**
Upper trunk forward rotation (°)	16 ± 7	22 ± 7	*
Pelvis forward tilt (°)	25 ± 6	20 ± 4	**
Pelvis leftward tilt (°)	19 ± 6	13 ± 6	**
Pelvis backward rotation (°)	-14 ± 9	-1 ± 10	**
Range of motion [PFC to REL]			
Pelvis forward rotation (°)	65 ± 14	92 ± 14	***

significant differences: * $p < .05$; ** $p < .01$; *** $p < .001$

Table 2: Significantly different maximum values of angular parameters and times of occurrence

	Catcher (CA)	**Infielder (IN)**	sig.diffs
Maximum values			
Pelvis forward rotation angular velocity (°/s)	586 ± 44	688 ± 139	**
Times of occurrence of max. values			
Elbow extension angular velocity (%Throw)	97.1 ± 1.2	95.8 ± 1.5	*

significant differences: * $p < .05$; ** $p < .01$; *** $p < .001$

%Throw: 0% is at PFC, 100% is at REL.

Of the 42 angular position parameters tested at PFC, SFC and REL, 15 showed significant differences (Table 1). The angular velocity parameters at REL did not show significant differences. Only the range of motion of the pelvis forward rotation showed a significant difference. Of the maximum angular velocity parameters, only the maximum pelvis forward rotation angular velocity and the time of occurrence of the maximum elbow extension angular velocity showed statistically significant differences between the groups (Table 2).

DISCUSSION: Success in the throws of baseball catchers and infielders relies on the achievement of the shortest possible throwing time and the largest possible ball velocity. Infielders had a longer step phase than catchers. This was because the infielders had to catch the ground ball with both hands while lowering the upper body, and subsequently execute a "crowhop" (Kindall, 1993) during the step phase. On the other hand, infielders also had a shorter stride phase than catchers, and no significant differences were found in the times of the arm cocking and arm acceleration phases. The shorter stride phase of the infielders essentially compensated for their longer step phase, and overall there was no significant difference between the total delivery times of the two groups. Since there was also no significant difference between the ball velocities of the two groups, we can say that the catchers and the infielders generated deliveries of similar overall quality.
In comparison to the catchers, the infielders had more upper trunk rightward tilt and more pelvis backward rotation at PFC, as well as more upper trunk and pelvis forward rotation, less upper trunk and pelvis leftward tilt, and less pelvis forward tilt at REL. In particular, the infielders demonstrated larger range of motion in the pelvis forward rotation than the catchers in the period from PFC to REL (Table 1). In addition, the infielders had greater maximum angular velocity of pelvis forward rotation than the catchers (Table 2). These results indicate that the horizontal rotations of upper trunk and pelvis were more likely to be the key techniques for the infielders, since the infielders had the smaller initial trajectory angle and height of release. Vice versa, since the catchers had a larger release height, the upper trunk and pelvis leftward tilts at REL were more likely to be key factors for the catchers.
The information obtained from the present study could be used to improve the delivery motions of baseball catchers and infielders.

CONCLUSION: Catchers and infielders use moderately different techniques to achieve deliveries of similar overall performance quality.

REFERENCES:

de Leva, P. (1996). Adjustments to Zatsiorsky−Seluyanov's segment inertia parameters. *Journal of Biomechanics*, 29, 1223-30.

Feltner, M. & Dapena, J. (1986). Dynamics of the shoulder and elbow joints of the throwing arm during a baseball pitch. *International Journal of Sport Biomechanics*, 2, 235-59.

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.

Kindall, J. (1993). *Sports Illustrated baseball: Play the Winning Way*. *Baserunnning* (pp 56-58). Maryland: Time, Inc.

Matsuo, T., Escamilla, R.F., Fleisig, G.S., Barrentine, S.W. & Andrews, J.R. (2001). Comparison of kinematic and temporal parameters between different pitch velocity groups. *Journal of Applied Biomechanics*, 17, 1-13.

Miyanishi, T., & Sakurai, N. (2011). Linear and angular contributions to ball velocity in the delivery motion among various levels of baseball infielder. *Portuguese Journal of Sport Sciences*, 11(Suppl. 2), 335-38.

Miyanishi, T., Sakurai, N., & Endo, S. (2015) Kinematic comparison of baseball delivery with regard to trunk and upper limb motions for the infielder among various levels of development. *Japan Journal of Physical Education, Health and Sport Sciences*, 60 (in press). [*http://dx.doi.org/10.5432/jjpehss.14066*]

Stodden, D.F., Fleisig, G.S., McLean, S.P., Lyman, S.L. & Andrews, J.R. (2001). Relationship of pelvis and upper torso kinematics to pitched baseball velocity. *Journal of Applied Biomechanics*, 17, 164-172.

Winter, D.A. (1990). *Biomechanics and Motor Control of Human Movement (2nd Ed.)*. New York: John Wiley & Sons, Inc.

Woltring, H.J. (1986). A Fortran package for generalized, cross-validatory spline smoothing and differentiation. *Advances in Engineering Software*, 8, 104-13.

Zatsiorsky, V.M., Seluyanov, V.N., & Chugunova, L.G. (1990). Methods of determining mass-inertial characteristics of human body segments. In G.G. Chernyi & S.A. Regirer (Eds.), *Contemporary Problems of Biomechanics* (pp 272-91). Boca Raton: CRC.