Relationship between Lower Extremity Motions and Release Time of Baseball Infielders while Fielding Grounders

Tetsuya Kita¹, Masayoshi Yamamoto² and Akira Maeda²

¹Oshima National College of Maritime Technology, 1091-1 Komatsu, Suo-Oshima, Oshima-gun, Yamaguchi 742-2193, Japan
E-mail: kita@oshima-k.ac.jp
²National Institute of Fitness and Sports in Kanoya, 1 Shiromizu, Kanoya, Kagoshima 891-2393, Japan

[Received April 30, 2013; Accepted February 20, 2014; Published online March 7, 2014]

When infielders field a ground ball, decreasing the interval from catching to releasing the ball (release time) increases the probability of outing a batter or runner. The present study examines the relationship between lower extremity kinematics and release time. Right-handed fourteen infielders caught a ground ball that was rolled towards them from a distance of 5 m and then they threw the ball as quickly as possible towards a net located 20 m in front. The interval between the catch to the left-foot lift-off (foot off phase), and the stride-foot contacting the ground after the step motion (stride phase) significantly correlated with release time. We assessed relationships between these phases and lower extremity movement. The angular variation of the joints of the right lower extremity from the catch to the right foot lift off significantly correlated with the foot off phase. Forward mid-hip and left foot variation significantly correlated with the stride phase. Velocity data did not significantly correlate with these phases, indicating that the size, rather than the speed of the fielding motion has a greater effect on release time.

Keywords: throwing, catching, footwork, kinematics

1. Introduction

The main role of infielders in baseball is to field ground balls, which involves the elements of movement time (amount of time required to catch a ball after it is hit by a batter), release time (interval from catching to releasing the ball) and flight time (amount of time the thrown ball takes to travel from the infielder to another baseman or catcher). Successful infielders must complete these processes before a batter or a runner reaches the next base. Among these processes, release time is most closely correlated with total time required to field ground balls (Matsunaga, 1979). Movement time appears to be dependent on the speed of the ground ball, and flight time appears to be dependent on the ability of the infielder to throw a fast ball and throwing distance. On the other hand, release time is affected only by the performance of the infielder. Rapid completion of the release will decrease the total time required to field a ground ball. An infielder must minimize the total time when little time is available, such as when a third base runner is trying to rush the home plate or when a fleet-footed batter bunts for a hit. Therefore, understanding the nature of the throwing motion of infielders is important. Although various theories regarding the throwing motion of infielders have been proposed (Edwards, 1966; Stockton, 1984; Hay, 1993), to our knowledge, this particular issue has not been investigated in detail. In addition, the technical requirements for decreasing release time have not been studied. Identifying the points where release time can be decreased will help players and coaches practice effectively.

Fielding involves a side step towards the throwing direction after catching a ground ball in addition to throwing. Thus, release time might be influenced by movement of the lower extremities. The size and speed of a fielding motion should be considered when analyzing whether release time is increased or decreased. The present study examines the relation-
ships between lower extremity kinematics and release time.

2. Methods

2.1. Subjects

Twelve college and two professional infielders (mean mass, height, and age: 67.0 ± 8.1 kg; 171.9 ± 7.0 cm; and 20.1 ± 1.5 years, respectively) provided written informed consent to voluntarily participate in the present study. The Ethics Committee of the National Institute of Fitness and Sports in Kanoya approved the test protocol. All participants were right-handed and injury-free at the time of data collection. Three, five and six of them were second basemen, third basemen and short stops, respectively.

2.2. Procedure

Each player was tested in an indoor laboratory (Figure 1). Spherical reflective markers (Motion Analysis Corp., Santa Rosa, CA, USA) were placed bilaterally at the lateral tip of the acromion, the great trochanter, the lateral epicondyle of the femur, the lateral malleolus, between the second and third metatarsal heads (toes), and the heel (Stodden et al., 2001; Werner et al., 2005). After stretching and completing a warm-up that included throwing, the participants performed the fielding test. They caught ground balls rolled to them from a distance of 5 m, and then threw the ball towards a 1.65 × 1.50 m net located 20 m in front of them. All participants were instructed to throw using the general footwork (Edwards, 1966; Stockton, 1984) of baseball infielders (Figure 2). Balls were rolled towards the participants by hand, and ball speeds were such that the participants could take one step forward to catch the ball. This test simulated the direction of throwing to the home plate, which is assumed to take the least amount of fielding time during an actual game. Each participant had to throw as soon as possible after catching it. After five trials, we analyzed the shortest release time for each participant. The speed of thrown ball was measured using a speed gun (ZETT Corp., Japan) for reference purposes (average ball speed of the 14 infielders: 28.0 ± 2.4 m/s). The ball speed of each participant did not show a major difference among the five trials.

Movement data from the reflective markers that were simultaneously recorded using 12 high-speed Eagle video cameras (Motion Analysis Corp., Santa Rosa, CA) at a rate of 400 Hz were mathematically processed. The three-dimensional (3D) coordinates of each marker were calculated using Cortex digitizing software (Motion Analysis Corp.), and then...
used to measure movements. The root mean square error in calculating the 3D location of a marker in the calibrated fielding area was <1.0 mm. The global Y-axis was defined as a vector from the center of the starting position of the infielder to the center of the net. The global Z axis was defined as a vertical vector. The cross product of the Y and Z vectors defined the global X-axis vector. The moments of catching and releasing the ball were determined from video data acquired by a digital high-speed video camera (EX-F1, Casio Computer Corp., Japan) located in front of the participants. These data were sampled at 300 Hz and synchronized with the motion data filmed with a lamp that could be lit by pressing a switch and located behind each participant. The analog signal of the lamp was recorded on a personal computer to analyze the motion data. Video data were also analyzed on a computer. Each fielding motion was viewed frame by frame. The frame taken just as the ball entered a participant’s glove was defined as the moment of the catch. The frame taken immediately before the ball was released from a participant’s finger was defined as the moment of ball release (Takahashi et al., 2005).

2.3. Definition of motion phases

Fielding motion was divided into several phases (Figure 2). Release time was the total time to field, or the interval from the catch to the release of the ball. The interval from the catch to right-foot contact was defined as the step phase. The interval from right-foot contacting the ground to ball release was defined as the throw phase. The step phase was subdivided into the foot off phase, defined as the interval from the catch to the left-foot lift off, and the hop phase, defined as the interval from the left-foot lift off to right-foot contact with the ground. The throw phase was also subdivided into the stride phase, defined as the interval from right to left-foot contact with the ground and the acceleration phase, defined as the interval from left-foot contact with the ground to ball release (Miyanishi and Morimoto, 2007). The moment of foot contact was automatically determined as the instant when the velocity of either the heel or the toe marker decreased to <1.5 m/s. The moment of foot off was determined as the instant when the velocity of the toe marker increased to >1.5 m/s. Velocities were determined with reference to a study of pitching motion (Escamilla et al., 1998). Before the velocities were calculated, all marker data were smoothed using a fourth-order, zero-phase shift and a digital Butterworth filter with a cutoff frequency of 10.0 Hz (MATLAB R2010a, The MathWorks Inc., Natick, MA, USA) (Werner et al., 2005).

2.4. Kinematic parameters

Variation and the average velocity of the mid-hip, feet, pelvis rotation angle and joint angles of the lower extremities while fielding a ground ball were calculated as kinematic parameters. The mid-hip was defined as the midpoint between the right and left great trochanters. The pelvic rotation angle was defined as the angle between a line connecting the great trochanter markers and the X-axis in the XY plane with reference to the method of Stodden et al. (2001). The angle of pelvic rotation was considered negative and positive when clockwise and counterclockwise, respectively. The angles or angular velocities of the hip, knee, and ankle joints were calculated using motion analysis software (nMotion Musculous, NAC Image Technology Inc., Tokyo, Japan). With nMotion, skeleton model is measured based on the subject’s age, height and weight using body size database embedded in the software. Joint positions are projected per frame by adjusting the model’s joint positions to the motion of markers measured by Motion capture. Joint angles are calculated in the software based on the definition of “How to display and measure the range of joint motion” (The Japanese Orthopaedic Association, 2001). These angles were in agreement with the anatomical angles. Each joint angle was defined as full extension at 180°. The toe marker was defined as the foot in kinematic analyses because all participants initiated foot off and foot contact from the toe.

2.5. Statistical analysis

Means and standard deviations of time and kinematic parameters during each fielding phase were analyzed. Relationships between the release time and time parameters of each phase were assessed using the Pearson product-moment correlation coefficient. Relationships between phases that significantly correlated with release time and lower extremity motion during each phase were subsequently, assessed using the same method. The sig-
Table 1  Temporal relationships to release time (n = 14)

| Duration (s)     | r   |
|------------------|-----|
| Step phase       |     |
| Foot off         | 0.222 ± 0.043 | .873* |
| Hop              | 0.075 ± 0.015 | .038  |
| Throw phase      |     |
| Stride           | 0.197 ± 0.032 | .651† |
| Acceleration     | 0.146 ± 0.034 | .261  |
| Release time     | 0.640 ± 0.068 |      |

Duration is shown as means ± standard deviation; r, correlation coefficients. Significant correlations with release time: *p<0.001, †p<0.05.

Table 2  Relationship between the foot off phase and kinematic of mid-hip and pelvic rotation data (n = 14)

| Variable                      | r   |
|-------------------------------|-----|
| Mid-hip variation             |     |
| X (m)                         | −0.19 ± 0.05 | −.587* |
| Y (m)                         | 0.61 ± 0.14  | .699† |
| Z (m)                         | 0.10 ± 0.04  | .414  |
| Average mid-hip velocity     |     |
| X (m/s)                       | −0.88 ± 0.23 | .138  |
| Y (m/s)                       | 2.76 ± 0.48  | −.114 |
| Z (m/s)                       | 0.44 ± 0.19  | −.107 |
| Pelvis rotation angle variation (°) | −23.4 ± 6.4 | −.328 |
| Average pelvis rotation angular velocity (°/s) | −107.6 ± 27.1 | .313 |

Data are shown as means ± standard deviation; r, correlation coefficients. Significant correlations with the foot off phase: *p<0.05, †p<0.01.

Significance level was set at p<0.05.

3. Results

Release time significantly correlated with the foot off and stride phases (Table 1). The hop and acceleration phases did not correlate with release time. We assessed the relationship between the foot off and stride phases that significantly correlated with release time and lower extremity movement.

Mid-hip variation towards X and Y significantly correlated with the foot off phase (Table 2). Pelvic rotation angular variation, average mid-hip velocity and average pelvic rotation angular velocity did not significantly correlate with the foot off phase. Figure 3 shows examples of varied of lower extremity joint angles in one participant. The motion from the catch to the right-foot lift-off was evaluated to determine the relationship between the foot off phase and the right lower extremity. Each joint of the right lower extremity extended until the right-foot lifted off (Figure 3a). The left hip joint extended and the knee joint flexed until the left foot lifted off (Figure 3b). The ankle joint was extended after flexing during this activity. We analyzed the total angular variation, the angular extensor variation from maximal flexion of the left ankle joint during the foot off phase and the average extensor angular velocity after maximum flexion of the left ankle joint. The extensor angular variation of each right lower extremity joint and the total angular variation of the left ankle joint significantly correlated with the foot off phase (Table 3). Only the average extensor angular velocity of the right knee joint significantly correlated with the foot off phase.

Mid-hip and left foot variation along the Y-axis showed a significant correlation with the stride phase (Table 4). Pelvis rotation angular variation, as well as average mid-hip and left foot velocity and average pelvic rotation angular velocity did not significantly correlate with the stride phase.
Table 3  Relationship between the foot off phase and kinematic data of lower extremity joints movement (n = 14)

| Variable                       | Catch | R. off | L. off | Variation | r         |
|--------------------------------|-------|--------|--------|-----------|-----------|
| R. hip angle (°)               | 106.5 ± 13.4 | 129.4 ± 13.0 | 22.9 ± 11.9 | .664†     |
| R. knee angle (°)              | 102.7 ± 17.4 | 131.9 ± 13.8 | 29.2 ± 13.3 | .857‡     |
| R. ankle angle (°)             | 68.4 ± 10.9  | 97.4 ± 7.8   | 29.0 ± 9.2  | .624*     |
| L. hip angle (°)               | 89.9 ± 6.5   | 117.6 ± 10.7 | 27.7 ± 9.3  | .153      |
| L. knee angle (°)              | 120.2 ± 18.9 | 88.8 ± 10.7  | −31.4 ± 24.8| −.439     |
| R. ankle angular velocity (°/s)| 99.9 ± 45.4  | .396       |         |           |
| R. knee angular velocity (°/s)| 126.0 ± 43.3 | .651*     |         |           |
| R. ankle angular velocity (°/s)| 129.7 ± 35.7 | .135     |         |           |
| L. hip angular velocity (°/s)  | −128.1 ± 41.0 | −.369   |         |           |
| L. knee angular velocity (°/s) | −136.1 ± 119.6 | −.243 |         |           |
| L. ankle extension angular velocity (°/s) | 103.3 ± 23.5 | −.391 |         |           |

Data are shown as means ± standard deviation; R. off, right-foot off; L. off, left-foot off; r, correlation coefficients. Significant correlations with the foot off phase: *p < 0.05, †p < 0.01, ‡p < 0.001.

Table 4  Relationship between the stride phase and kinematic data of lower extremities (n = 14)

| Variable                             | r         |
|--------------------------------------|-----------|
| Mid-hip variation                    |           |
| X (m)                                | −0.01 ± 0.05 | −.104 |
| Y (m)                                | 0.54 ± 0.12  | .849* |
| Z (m)                                | −0.05 ± 0.03 | .083  |
| Average mid-hip velocity             |           |
| X (m/s)                              | −0.05 ± 0.28 | −.011 |
| Y (m/s)                              | 2.70 ± 0.37  | .251  |
| Z (m/s)                              | −0.24 ± 0.14 | .327  |
| Left foot variation                  |           |
| X (m)                                | 0.13 ± 0.13  | .019  |
| Y (m)                                | 1.03 ± 0.17  | .725* |
| Z (m)                                | 0.01 ± 0.03  | .029  |
| Average left foot velocity           |           |
| X (m/s)                              | 0.64 ± 0.70  | −.035 |
| Y (m/s)                              | 5.22 ± 0.62  | −.289 |
| Z (m/s)                              | 0.05 ± 0.14  | −.051 |
| Pelvis rotation angle variation (°)  | 11.7 ± 10.3 | .448  |
| Average pelvis rotation angular velocity (°/s) | 55.8 ± 47.4 | .240  |

Data are shown as means ± standard deviation; r, correlation coefficients. Significant correlations with the stride phase: *p < 0.01, †p < 0.001

4. Discussion

Published instructions to baseball infielders about how to catch or throw balls simply advise players to smoothly execute a series of motions (Edwards, 1966; Stockton, 1984). Technical instructions to players have been ambiguous because infielder’s fielding motions have never been thoroughly analyzed. The release time and the time to each fielding phase described herein would be associated with motion when players practice fielding. The foot off phase correlated the closest with release time during the step phase. Decreasing the foot off phase, namely, rapidly lifting the right and then the left foot off the ground after catching a ground ball might reduce release time. The present study found that the foot off phase was the most time consuming of all phases. Therefore, this phase will probably be the easiest of all motions involved for a player to be conscious of while fielding grounders. The hop phase that occurs during the second half of step phase did not correlate with release time. Air time during infielder movements, such as the side step (crow-hop) after catching the ball (Edwards, 1966) might not influence release time. The stride phase significantly correlated with release time during the throw phase. A significant correlation between the acceleration phase and release time was notably absent. The acceleration phase is the last among fielding phases.
Although this cannot be concluded from only the present findings, we speculate that release time might be dictated before the throwing arm begins to accelerate.

Mid-hip variation leftwards and forwards, as well as the extensor angular variation of each right lower extremity joint significantly correlated with the foot off phase, whereas upward mid-hip variation notably did not. Coaches usually advise infielders to catch with the mid-hip in a low position and step while maintaining this mid-hip position. A low mid-hip position probably facilitates catching batted balls. However, if the mid-hip is positioned too low, lifting the foot might be too late to shift the step motion. This is because lifting the right foot after catching a ball is associated with extension of the lower extremity joints. Participants with a longer foot off phase had lowered their mid-hips excessively, which probably increased the extensor movement of the right lower extremity joints after the catch. These infielders might have lifted off their right foot by increasing their mid-hip movement leftwards and forwards, because they had been preferentially trained not to lift their hips after catching. Our findings indicated that the right lower extremity joints should be extended to some degree to facilitate lifting the right foot after catching, which in turn would decrease the foot off phase. The total angular displacement of the left ankle joint significantly correlated with the foot off phase. The left ankle joint was flexed during the early part of this interval. Then infielders lifted off their left foot by extending the ankle joint. This characteristic movement seems important for lifting off the left foot. We could not determine how an infielder could be aware of the movement of the left foot during this interval. Further information is required about decreasing the foot off phase of infielders, with variations in ground reaction force before and after catching a ball. Only the average angular extensor velocity of the right knee joint significantly correlated with the foot off phase. The reason why this correlation was evident only in the right knee joint is unknown.

Forward mid-hip and left foot variation significantly correlated with the stride phase. We could not determine from our data whether participants with an elongated stride phase also had a longer stride during the throw phase. However, the 28.0 m/s average ball velocity of each participant indicated that they were probably not trying to lengthen their stride (Chu et al., 2009) and that to do so was unnecessary. A difference of 10 to 20 cm from the standard deviation of forward variation of the left foot will determine whether the stride phase is long or short. Although this is a small movement, the stride phase might be shortened simply by making an infielder aware of the difference. The stride motion by an infielder during the throw phase is more rapid than that of a pitcher. How an infielder actually performs such movement requires further investigation. Velocity data did not correlate with the stride phase. Overall, the present study findings indicated that the size would affect release time rather than the speed of the fielding motion.

5. Conclusion

We analyzed the technical factors of the lower extremities that involved in reducing release time while fielding grounders. The foot off and the stride phases significantly correlated with release time. Decreasing the lengths of these two phases would reduce release time. Although we can only suggest the influence of lower extremity motions upon time parameters while fielding grounders, pieces of specific information will help infielders and coaches during fielding practice. Our analysis of fielding motion indicated that a large body movement might be unnecessary to decrease release time. After catching a ground ball, the angular variation of extensors of the right lower extremity joints would be smaller to decrease the foot off phase. Thereafter, variation of the stride foot towards throwing direction would decrease to shorten the stride phase. We hope that these findings will trigger a review of infielder training that has hitherto been implemented based on subjective determinations by coaches. Further investigation is needed to elucidate the step and throwing movements involved in fielding grounders.

References
Chu, Y., Fleisig, G. S., Simpson, K. J., and Andrews, J. R. (2009). Biomechanical comparison between elite female and male baseball pitchers. J. Appl. Biomech., 25: 22-31.
Edwards, D. (1966). Baseball coach’s complete handbook. West Nyack, NY: Parker Publishing.
Escamilla, R. F., Fleisig, G. S., Barrentine, S. W., Zheng, N., and Andrew, J. R. (1998). Kinematic comparisons of throwing different types of baseball pitches. J. Appl. Biomech., 14: 1-23.
Hay, J. G. (1993). The Biomechanics of Sports Techniques 4th ed. (pp. 198-224). Englewood Cliffs, NJ: Benjamin Cum-
Matsunaga, N. (1979). Fielding of baseball infielders. J. Health Phys. Educ. Rec., 29: 546-549. (in Japanese)

Miyanishi, T., and Morimoto, Y. (2007). A case study of the effect of skill training on the pitching motions of collegiate baseball pitchers. Japan J. Phys. Educ. Hilth. Sport Sci., 52: 361-381. (in Japanese)

Stockton, B. A. (1984). Coaching baseball: skills & drills: the American Coaching Effectiveness Program level 2 baseball book. Champaign, Ill: Human Kinetics.

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

Takahashi, K., Ae, M., Fujii, N., Shimada, K., Kawamura, T., and Koike, S. (2005). Kinematic comparison of pitching motion of baseball pitchers whose ball velocities were significantly different. Jpn. J. Biomech. Sports Exerc., 9: 36-52. (in Japanese)

The Japanese Orthopaedic Association (2001). How to display and measure the range of joint motion. J. Clin. Sports Med., 18: 104-110. (in Japanese)

Werner, S. L., Guido, J. A., McNeice, R. P., Richardson, J. L., Delude, N. A., and Stewart, G. W. (2005). Biomechanics of youth windmill softball pitching. Am. J. Sports Med., 33: 552-560.

Name:
Tetsuya Kita

Affiliation:
Oshima National College of Maritime Technology

Address:
1091-1 Komatsu, Suo-Oshima, Oshima-gun, Yamaguchi 742-2193, Japan

Brief Biographical History:
2010-2013 Doctoral Course, Graduate School of Physical Education, National Institute of Fitness and Sports in Kanoya 2013- Oshima National College of Maritime Technology

Main Works:
•Kita, T., Furukawa, N., Komatsu, S., Kameda, M., and Mae-da, A. (2013). Influence of high intensity maximal pedaling-training on 30 m sprint running performance in baseball players. J. Train. Sci. Exerc. Sport., 25(1): 69-78. (in Japanese).

Membership in Learned Societies:
•Japan Society of Physical Education, Health and Sport Sciences
•Japanese Society of Physical Fitness and Sports Medicine
•Japan Society of Training Science for Exercise and Sport