KINEMATIC AND KINETIC COMPARISON OF DELIVERY MOTION AMONG VARIOUS LEVELS OF BASEBALL INFIELDER

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SUMMARY
The purpose of this study was to quantify and compare the kinematic and kinetic differences of the delivery motion among various levels of baseball infielder. A total of 54 infielders from the junior high school (group J), high school (group H), and college (group C) levels were analyzed using a 3D high-speed video analysis. Forty-six kinematic and 9 temporal variables, and both 14 kinetic and temporal variables in the upper trunk, pelvis, throwing shoulder and elbow were measured. Ball velocity was significantly larger with increase of the level, although no significant difference was found in the anthropometric data between groups H and C infielders. Significant differences were found in 16 kinematic and 3 temporal variables, and 10 kinetic and 5 temporal variables among the levels of development. The difference of the ball velocity demonstrated between group J and the older group infielders was most likely due to both greater muscle strength and longer segment length, while the difference between groups H and C infielders was due mainly to higher skill progression. These results provide a basis for understanding the possible improvement of performance with decreased risk of overuse injury from one level to the next.

INTRODUCTION
In the throwing study of the baseball, pitching biomechanics have been well documented [1,2]. We know of no studies that report on the delivery motion of position player associated with the motion variations among various levels. To reach in-depth knowledge on the baseball throwing, it should be studied not only pitching motion, but also delivery motion of the position player. The purpose of this study was to quantify and compare the kinematic, kinetic, and temporal differences of the delivery motion among various levels of development.

METHODS
Healthy 54 skilled right-handed male baseball infielders, including 18 junior high school (age 13.2 ± 0.7 yrs, BH 1.61 ± 0.06 m, BW 52.7 ± 8.4 kg: group J), 20 high school (15.8 ± 0.8 yrs, 1.72 ± 0.06 m, 65.4 ± 7.4 kg: group H), and 16 college (19.8 ± 0.8 yrs, 1.72 ± 0.04 m, 68.8 ± 5.7 kg: group C) recruited in this study. All participants signed assent forms, and informed consent for groups J and H infielders were obtained from their parents prior to the experiments. 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 full effort toward the target (width: 1.4 m; height: 1.7 m) set up at the first base, 35 m away. These deliveries were recorded using two high-speed 250 Hz genlocked video cameras (HSV-500C, NAC, Japan).
A single trial of each infielder, which the ball hit on the target, was selected for the following analysis. The two-dimensional coordinates of 23 body landmarks including the ball centre recorded with each camera were manually digitized using a Video Motion Analysis System (Frame-DIAS, DKH, Japan). The three-dimensional coordinates of the body landmarks were calculated using the direct linear transformation (DLT) technique, and then were smoothed using quintic spline functions as selected by the optimal cutoff frequencies (4-24 Hz) for each body landmark coordinate. Forty-six kinematic and 9 temporal variables, and both 14 kinetic (joint torques and forces) and temporal variables in the upper trunk, pelvis, throwing shoulder and elbow were measured based upon the methods of previous studies [2]. A one-way analysis of variance (ANOVA; unpaired) was performed to assess all variables between the three levels. A Bonferroni correction was also used to determine the difference between the levels. The significance levels were set at the p < .05, p < .01, and p < .001 for each test.

RESULTS AND DISCUSSION
Ball velocity was significantly larger with increase of the level. The height of ball release was significantly higher in group J infielders than in groups H and C infielders. The angle of release was significantly larger in group J infielders than in groups H and C infielders (Table 1). These results shows the evidence that the changes in ball velocity, angle of release and height of release are all inter-related, especially in the youngest group infielders the smaller ball velocity strongly influence the changes in those variables due mainly to the fixed target distance and height. The kinematic differences exhibited among the three levels were observed in the upper trunk and pelvis movements, rather than the throwing arm. Group J infielders had greater upper trunk and pelvis leftward tilts (Fig.1), greater elbow extension (Fig.2), and less joint kinetics productions. Group H infielders had greater upper trunk and pelvic rightward tilts, pelvis backward orientation (Fig.1), shoulder horizontal adduction, and elbow flexion (Fig.2). Group C infielders stood more erect, and had less pelvis backward orientation (Fig.1), greater elbow flexion (Fig.2), greater the ranges of motion for the shoulder external-internal rotation and for the elbow flexion-extension, and generated greater shoulder and elbow joint kinetics.
The mean body height and body weight in the groups H and C infielders was significantly larger than in the group J infielders, although no significant difference in the anthropometric data between the groups H and C infielders. Thus, the difference of the ball velocity demonstrated between group J and the older group infielders was most likely due to both greater muscle strength and longer segment length, while the difference between groups H and C infielders was due mainly to higher skill progression to induce greater kinetic productions.
CONCLUSIONS
The kinematic and kinetic differences of the delivery motion among various level infielders were identical in this study. The results suggest that a specified technique observed each throwing level could be adopted to increase the efficiency of the throw, which would allow an infielder to improve the performance with decreased risk of overuse injury.

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REFERENCES

![Figure 1](image1.png)

**Figure 1**: Mean angular displacement patterns of upper trunk and pelvis among the three levels of development. The black rectangle above each graph indicates that the significant level among the levels is $p < .05$. [PFC: at the instant of pivot foot contact, SFC: stride foot contact, MER: shoulder maximum external rotation, and REL: ball release]

![Figure 2](image2.png)

**Figure 2**: Mean angular displacement patterns of throwing shoulder and elbow among the three levels of development. The black rectangle above each graph indicate that the significant level among the levels is $p < .05$.

| Table 1: Selected kinematic variables at the instant of ball release (Significant differences: * $p < .05$, ** $p < .01$, *** $p < .001$). |
|---|---|---|---|
| Ball Velocity (m.s$^{-3}$) | 28.3 ± 1.7 | 31.8 ± 0.9 | 33.2 ± 1.5 |
| Angle of Release (deg.) | 10 ± 3 | 8 ± 1 | 7 ± 1 |
| Height of Release (% Body Height) | 90 ± 5 | 83 ± 7 | 84 ± 4 |
| Shoulder Horizontal Adduction (deg.) | 5 ± 10 | 11 ± 8 | 1 ± 7 |
| Upper Trunk Leftward Tilt (deg.) | 17 ± 8 | 9 ± 8 | 13 ± 6 |
| Pelvis Leftward Tilt (deg.) | 18 ± 8 | 9 ± 9 | 13 ± 6 |
| Pelvis Backward Orientation (deg.) | -7 ± 10 | -12 ± 7 | -1 ± 10 |

Notes: Significant differences between (a) group J and group H, (b) group J and group C, and (c) group H and group C.