Three-dimensional Kinematic Analysis Of Throwing Motion Focusing On Correlation Between Center Of Gravity Of The Body And Pelvic Rotation At Foot Plant

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Introduction: Various factors have been proposed and investigated as mechanism of shoulder injuries in baseball pitchers. In order to effectively prevent and treat these injuries and enable the injured player to return to play without recurrence, optimization of throwing kinematics based on accurate evaluation of the throwing motion is mandatory. Among the potential causative mechanisms, “opening up too soon” in throwing sequence characterized by earlier trunk and pelvis rotation in cocking phase has been reported as an important feature leading to the throwing injuries. lthough there have been some biomechanical studies investigating this phenomenon, analysis was limited to relationship of upper and lower body segments. In this study, we evaluated the three-dimensional kinematics of each locomotive segment throughout the throwing motion to clarify the factor inducing “opening up too soon”. Analysis of the kinematic data was focused on pelvis and trunk rotation in cocking phase during throwing motion. We hypothesized that multiple factors such as position of each motion segment, time dependent displacement of center of gravity as well as velocity and timing of trunk and pelvic rotations during throwing motion are associated with occurrence of this phenomenon.

Methods: (Subjects) Motion analysis was performed for 335 pitchers with various skill levels. Subjects who could not throw a fast ball due to shoulder or elbow pain were excluded from the study population. Age of the subjects ranged from 8 to 38 years(Ave.17.0±5.19), ball speed of them ranged from 52 to 132 km/h (Ave.105.4±14.85), height and weight of them ranged from 130 to 191cm (Ave.169.8±11.45), from 20 to 100kg (Ave.62.9±13.59). All study participants read and signed a consent form prior to participation in this study.
(Motion analysis system) Throwing motion was analyzed using an infrared type motion capture system (ProReflexTM MCU-500+, Qualisys, Sweden). Seven CCD cameras were set up around the regulation-size pitching mound. For motion analysis, 36 reflective plastic spheres were attached to subject’s skin on the representative anatomical locations by an experienced physical therapist. Three-dimensional positions of the markers during the motion were recorded at a rate of 500 Hz by means of the cameras. Ball speed was measured by a speed gun (SpeedMax2, Mizuno, Japan). After a warm-up, each subject was asked to throw a fastball from a pitching mound over 3 appropriate trials and the fastest pitch was adopted for the subsequent analysis.
(Data analysis) In the analysis, rigid-body model was constructed and the kinematic parameters were calculated based on the local coordinate ystem. The local coordinate system was established on each segment; 1) shoulder joint, 2) pelvis, and 3) femur. These coordinate systems were defined mathematically based on the localization of the anatomical landmarks. To describe six-degree-of freedom joint motion, Euler angle sequence was used. The throwing motion was divided into 4 phases by 5 points during the sequence: 1) wind up phase, 2) cocking phase, 3) acceleration phase, and 4) follow through phase. In the assessment, following kinematic variables were analyzed; pelvic and trunk rotation angles, angular velocity of pelvic and trunk rotation, and distance between the centers of gravity of the upper and lower extremities.

Results: The pelvic rotation angle at foot plant was significantly correlated with trunk anterior/posterior flexion, right/left bend, and hip extension/flexion angles on the non-throwing side ($r=0.31$ $p<0.001$, $r=-0.57$ $p<0.001$, and $r=0.70$ $p<0.001$ respectively) and hip abduction/adduction angle on the throwing side ($r=0.62$, $p<0.001$). In the analysis of relationship among these parameters, distance between the centers of gravity of the upper and lower extremities at foot plant was significantly correlated with the pelvic rotation angle ($r=0.45$ $p<0.001$) regarding front-rear direction, while the corresponding values in horizontal and vertical directions were not significantly correlated to pelvic rotation angle at foot plant ($r=0.002$ and $r=-0.25$ $p<0.001$ respectively).
Table 1. Correlation between the pelvic rotation angle and orientation of trunk and bilateral hip joint at foot plant.

	Pelvis Left (+) / Right (-) rotation (°) at FP	
	Correlation value	*p* value
Trunk orientation (°) at FP		
Extension (+) / Flexion (-)	$r = 0.31$	$p < 0.001$
Right (+) / Left (-) bend	$r = -0.57$	$p < 0.001$
Left (-) / Right (+) rotation	$r = 0.18$	$p = 0.001$
Hip orientation (°) at FP		
Non-throwing side		

Discussion: These results showed that pelvic rotation angle at foot plant increased with increased posterior flexion (extension) and side bend of the trunk on the non-throwing arm side, while hip flexion on the non-throwing side and hip abduction on the throwing side were also correlated with pelvic rotation angle at foot plant. Based on the analysis of time sequence during hrowing motion, it can be speculated that excessively early occurrence of trunk rotation prior to foot plant may induce increased pelvic rotation representing as “opening up too soon” phenomenon. Additionally, shift of center of gravity toward the throwing direction (increased distance between the centers of gravity of the upper and lower extremities) was also shown to significantly correlate with excessive pelvic rotation, inducing the potentially harmful throwing kinematics. Because the foot on the non-throwing side is a fulcrum for delivering the twisting energy of the pelvis and shoulder to the arm at foot plant, it is important to avoid early trunk rotation and forward deviation of center of gravity in prevention of the “opening up too soon” phenomenon.

Significance: The results of this study can help construct systematic and effective measures to prevent and manage shoulder problems in baseball pitchers through correction of throwing motion kinematics.

Acknowledgments:

References:

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