COMPARISON OF PELVIS KINEMATICS DURING THE BASEBALL PITCH: FATIGUED AND NON-FATIGUED CONDITIONS

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The purpose of this study was to identify changes that occur in pelvis kinematics as baseball pitchers fatigue during extended performances. Kinematic data describing the actions of the pelvis were collected using electromagnetic tracking techniques and calculated using the ISB recommendations. There were significant differences between non-fatigued and fatigued conditions in the angle of lateral pelvis flexion at maximum external rotation and release ($p<0.05$). As for the rate of axial pelvis rotation, no differences were observed between the non-fatigued and fatigued states. These results indicate that fatigue may play a major role in pitchers altering the actions of the pelvis during pitching.

KEYWORDS: Pitching, kinematics, fatigue

INTRODUCTION: Baseball pitching is often considered the most dynamic overhand movement in sports. Its violent nature repeatedly subjects the body to high magnitudes of joint kinetics (Adams, 1991). It is currently thought that the repeated nature of these stresses may be related to the high incidence of shoulder injury observed in baseball pitchers. From a biomechanical perspective, the manner in which each segment involved in pitching allows for optimal momentum transfer through larger segments to the smaller segments is commonly referred to as the kinetic chain (Kibler, 1991). In order for this momentum transfer to be optimized, the actions of the trunk and pelvis must be exceedingly efficient. Although it has become evident that control of the pelvis plays a major role in both performance and injury prevention (Werner et al., 2001; Aguinaldo et al., 2007; McKenzie, 2008), there are no known studies investigating how the kinematics of the pelvis are altered as pitchers fatigue. Therefore it was the purpose of this study to compare pelvic kinematics in baseball pitchers, while throwing the fastball, during non-fatigued and fatigued conditions.

METHODS: Ten male baseball pitchers (17.4yrs ± 3.27 yrs, 76.9 kg ± 12.2 kg, 178.2cm ± 7.2 cm) volunteered to participate. All subjects had recently finished their collegiate fall baseball season, and were deemed free of injury. Throwing arm dominance was not a factor contributing to participant selection or exclusion for this study.

Kinematic data were collected using The MotionMonitor™ electromagnetic tracking system (Innovative Sports Training, Chicago IL). Subjects had a series of electromagnetic sensors attached to the medial aspect of the torso and pelvis at the C7 and S1 locations respectively (Pope & Panjabi, 1985), as well as the distal/posterior aspect of the throwing humerus (Figure 1). To determine the instant of foot contact, a Bertec 40x60 cm force plate (Columbus, OH) was set to collect ground reaction forces at a rate of 1000 Hz. Sensors were affixed using double sided tape and then wrapped using flexible hypoallergenic athletic tape. Following the attachment of the electromagnetic sensors, a fourth sensor was attached to a stylus and used to digitize the palpated position of various bony landmarks (Myers et al., 2005). To accurately digitize selected bony landmarks, subjects stood in the neutral anatomical position while digitization was being completed.

After all sensors were attached subjects completed their own pre-competition warm-up. After subjects completed their warm-up, five maximal effort fastballs were thrown to a catcher located regulation distance from the pitching mound (18.44m). The pitching surface was positioned so that the subject's stride foot would land on top of the 40 x 60 cm Bertec force plate (Bertec Corp, Columbus, Ohio) which was anchored into the floor. After five fastballs for strikes were thrown, subjects threw a 2kg ball into a portable rebounder until they reported their maximum perceived fatigue on a scale of 0 to 3. Once the subjects reported maximum perceived fatigue, they returned to the mound to throw five additional fastballs for strikes. Because preliminary data analysis indicated that current pitchers were remarkably consistent with their mechanics (low intra-subject variability), only those data from the fastest pitch deemed strike for non-fatigued and fatigued conditions were selected for analysis.

Throwing kinematics for right handed subjects were calculated using the standards and conventions for reporting joint motion recommended by the International Shoulder Group of the International Society of Biomechanics (Wu et al., 2002; Wu et al., 2005). Briefly, raw data regarding sensor orientation and position were transformed to locally based coordinate systems for each of the respective body segments. Euler angle decomposition sequences were used to describe both the position and orientation of both the pelvis and trunk relative to the global coordinate system (Wu et al., 2002; Wu et al., 2005). The use of these rotational sequences allowed the data to be described in a manner that most closely represented the clinical definitions for the movements reported (Myers et al., 2005).

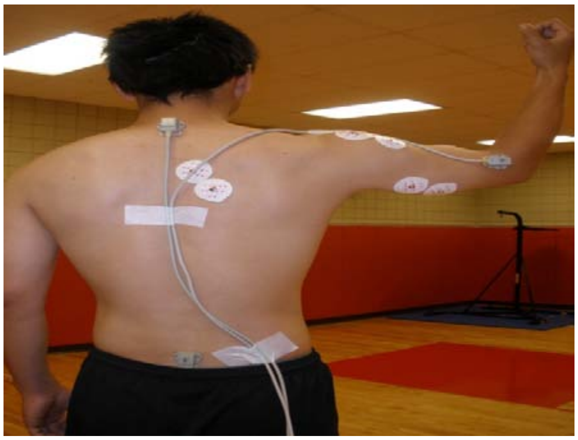

Figure 1. Sensor attachment for the humerus and trunk in the current study.

Throwing kinematics for left handed subjects were calculated using the same conventions; however, it was necessary to mirror the world z axis so that all movements could be calculated, analyzed, and described from a right hand point of view (Wu et al., 2002; Wu et al., 2005). Pitch velocity was also measured using a standard calibrated radar gun (Jugs, Tualatin, OR).

For each subject, means and standard deviations were calculated for each pelvis parameter. Prior to testing for mean differences the nature of the distribution was analyzed, and after the data were deemed to be normally distributed paired sample *t*-test were used to compare mean values between the non-fatigued and fatigued trials at following intervals: 1) stride foot contact (FC); 2) maximum shoulder external rotation (MER); 3) ball release (REL); and 4) maximum shoulder internal rotation (MIR). For each of the analyses, age was the independent variable and the kinematic parameter being analyzed was the dependent variable. Because the data were analyzed at four independent intervals, the level of significance for kinematic data was adjusted and set at alpha = 0.01. For additional information, the difference in pitch velocity was also tested using the same techniques.

RESULTS and DISCUSSION: The results of kinematic analyses are shown in Table 1. Of the 12 pelvis parameters analyzed in the current study, 2 were found to differ significantly between the non-fatigued and fatigued conditions. It has been previously suggested that throughout the pitching motion, kinematic alterations in the actions of proximal segments may result in kinematic alteration in the actions of distal segments (Putnam, C.A., 1993; Aguinaldo et al., 2007). Based on this logic, the actions of the pelvis could alter the actions of each subsequent segments involved in the pitching motion. The difference in the angle of lateral pelvic tilt at both MER and REL may result in an increase in the linear distance between the throwing hand and body. Previous investigations indicate that maximum elongation of the distance between the body and hand takes place during the arm cocking phase (Braun et al., 2009). This elongation occurs even when the vertical axis of the torso remains constant and may be exacerbated as the angle of lateral pelvis tilt increases in the fatigued state. As this distance increases at MER, there would be a resulting increase in the angle of external rotation. The combination of these actions could result in an increase in the magnitude of compressive force necessary to stabilize the shoulder joint.

Table 1. Kinematic differences between pitchers in the fatigued and non-fatigued states at specific instances throughout the pitching motion (Group mean ± SD)

	Non-fatigue (n=9)	Fatigue (n=9)	Sig.
FC			
Pelvis Posterior Tilt (^{o})	1.8 ± 4.1	1.7 ± 3.6	
Pelvis Leftward Tilt (^{o})	-4.4 ± 11.6	-4.2 ± 11.1	
Pelvis Leftward Rotation (^{o}/s)	307.5 ± 89.5	287.6 ± 57.9	
MER			
Pelvis Anterior Tilt (^{o})	-9.8 ± 14.9	-10.4 ± 11.3	
Pelvis Leftward Tilt (^{o})	-10.8 ± 11.8	-14.8 ± 11.3	*
Pelvis Leftward Rotation (^{o}/s)	268.8 ± 68.7	202.9 ± 54.3	
REL			
Pelvis Anterior Tilt (^{o})	-12.04 ± 14.29	-11.58 ± 12.81	
Pelvis Leftward Tilt (^{o})	-3.36 ± 5.24	-6.82 ± 3.87	*
Pelvis Leftward Rotation (^{o}/s)	167.8 ± 63.3	168.1 ± 53.4	
MIR			
Pelvis Anterior Tilt (^{o})	-8.37 ± 5.18	-7.62 ± 6.81	
Pelvis Leftward Tilt (^{o})	-1.18 ± 2.86	-2.69 ± 3.78	
Pelvis Leftward Rotation (^{o}/s)	136.2 ± 61.0	133.8 ± 50.4	

Note:

Following data collection sessions, it was determined that one subject supplied incorrect information on the medical history. Therefore, those data were removed from the analysis.
*** indicates a significant difference between fatigue levels ($p < 0.05$).**

Additionally, as pitchers fatigue, there is a decrease in the rate of axial pelvis rotation. This decrease in the rate of pelvis rotation may result in pitchers transferring less angular momentum through the remaining body segments used in pitching. As the magnitude of this transferred momentum decreases, there may be a corresponding loss of pitch velocity. In the current study, it was observed that pitchers experienced a relative loss of pitch velocity (75 mph in non-fatigued state; 72 mph in fatigued state) once deemed fatigued. Although this difference was not significant, it should be considered that pitchers may alter the actions other segments in an attempt to make-up for the loss of pitch velocity.

CONCLUSION: It appears pelvis kinematics are altered as a baseball pitcher fatigues. Functionally, alterations in pelvic kinematics would affect the core or lumbopelvic-hip complex. It is the lumbopelvic-hip complex that essentially supports the torso and allows proximal stability for distal mobility (Kibler, 1991; Putnam, 1993). In addition, the lumbopelvic-hip complex is the fundamental link for efficient energy transfer from the lower extremity to the upper extremity. As pitchers fatigue, alterations in the actions of the pelvis may result in an increase in the stresses experienced by the body. When these stresses are increased, their cumulative effect on the structural integrity of the joints may be compromised. However, these results should be interpreted with caution as this study incorporated a relatively small sample from a pool of convenient subjects. Continued testing is needed to determine if these results can be observed in a larger, more representative sample.

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