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Association between Pelvic Motion and Hand Velocity
in College-Aged Baseball Pitchers

By

William Horlbeck

A plan B paper submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

HEALTH AND HUMAN MOVEMENT

Approved:

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Utah State University
Logan, UT
2014

Abstract

Previous research suggests that pelvic motion is closely related to pitching performance over the course of a season. Few studies have examined pelvic motion and its relationship to an acute pitching variable. Therefore, the purpose of this study was to investigate the relationship between pelvic motion and hand velocity in college-aged pitchers. Nine healthy club baseball team pitchers performed two tests: A pelvic motion test, and a hand velocity test during a pitch. The pelvic motion test required participants to lift their kicking leg 10 cm off the ground, then hold that position for two seconds before returning to a double leg stance. This procedure was repeated five times. The hand velocity test required participants to perform five maximal-effort pitches thrown from a wind-up position. Motion of the pelvis and hand during the tests was recorded with a passive infrared marker-based motion analysis system (Vicon). Angular displacements (tilts) of the pelvis and peak hand velocity were computed from coordinate data using Nexus software (Vicon). Given the low sample size, ninety-nine percent confidence intervals were used to interpret the correlation (Pearson's r) between pelvic motion and hand velocity. The intervals were computed using the bootstrap procedure ($n=100$). Based on ninety-nine percent confidence intervals, we observed a negative correlation between anterior-posterior pelvic tilt and hand velocity (99% CI: $-0.45 < r < -0.64$) and a positive correlation between medial-lateral pelvic tilt and hand velocity (99% CI: $0.29 < r < 0.53$). These data imply that pelvic motion in the sagittal plane is associated with a decrease in hand velocity, while motion in the frontal plane is associated with

an increase in hand velocity. Medial-lateral pelvic motion occurs in the same plane as the pitch itself, which could contribute to the overall effectiveness of the kinetic chain in the pitching motion, thus creating a faster pitch.

Introduction

Wilk et al. (200) defined pitching as a “complex movement pattern that requires flexibility, muscular strength, coordination, synchronicity of muscle firing, and neuromuscular efficiency.” The pitching motion can be divided into six phases: (a) wind-up, (b) stride, (c) arm cocking, (d) acceleration, (e) deceleration and (f) follow-through (Fleisig, Andrews, & Dillman, 1995). These phases are performed sequentially, where energy is created within the legs, transferred through trunk and into the upper extremity, resulting in a rapid acceleration, and subsequent deceleration of the throwing arm (Seroyer et al., 2010).

Proper baseball pitching mechanics are crucial for injury prevention, and maximizing a pitcher’s success. Previous research suggests that inconsistent throwing mechanics decrease pitching performance and increase the likelihood of injury (Fleisig, Barrentine, Zhen, Escamilla, & Andrews, 1999). To improve control of pitch delivery, it is important that coaches and athletes are knowledgeable of proper mechanics, and practice them repetitively.

The baseball pitch involves a transfer of mechanical energy through the segments of the kinetic chain, from the lower extremity to the throwing arm (Chaudhari, McKenzie, Borchers, & Best, 2011; Robb et al., 2010; Scher et al., 2010). The motion and control of each segment, as well as the coordination and timing between each segment, helps to increase the energy transferred to the

ball at release. (Feltner, & Dapena, 1989; Putnam 1993; Seroyer et al., 2010; Wilk et al., 2000). If executed properly, each body segment will contribute to the energy of the pitch, increasing the throwing velocity at the distal aspect of the chain.

A considerable portion of the pitching mechanics literature has focused on the shoulder and elbow, while few studies have addressed the pelvic region. Studies that have investigated the pelvic region typically focus on mechanics during the later stages of the pitching sequence. (Fleisig, 1994; Stodden, Fleisig, McLean, & Andrews, 2005; Stodden, Fleisig, McLean, Lyman, & Andrews, 2001; Wight, Richards, & Hall, 2004). Research investigating the role of pelvic motion during the wind-up phase is limited. Chaudhari et al. (2011) investigated the relationship between pelvic motion in the sagittal plane during the transition period from a bipedal to unipedal stance and pitcher's total innings pitched, batting average against, strikeouts per inning, walks per inning, and walks plus hits per innings pitched. A test that closely mimics the wind-up phase was used to measure pelvic control. The researchers observed that pitchers who exhibited less pelvic motion in the sagittal plane during the pelvic test performed better through the course of a season, indicating that pelvic mechanics are crucial to overall performance.

While Chaudhari et al. (2011) observed an association between pelvic motion in the sagittal plane and performance over the length of a season, the acute effect of pelvic motion on pitching mechanics has not been addressed. Additionally, while anterior-posterior (AP) tilt is important, it is only one

component of total hip motion. Therefore, the purpose of this study was to investigate the association between biplanar pelvic motion and hand velocity during the execution of a fastball pitch.

Methods

Participants

Prior to participation, all athletes completed an informed consent approved by the Utah State University Institutional Review Board. Nine National Club Baseball Association pitchers from a university club baseball team served as participants. All pitchers were not injured or recovering from injury at the time of testing. Participants had a mean mass, height, and age of 86.13 ± 18.05 kg, $1.84 \pm .04$ m, and 21.33 ± 2.45 years, respectively. All participants had at least five years of competitive pitching experience. Testing took place in the Utah State University Biomechanics Laboratory. Participants were instructed to wear spandex shorts and no shirt to ensure correct marker location, and to limit the movement of markers from their anatomical landmarks.

Instrumentation

A custom-built pitching mound was constructed to meet NCAA baseball regulations. From the mound, pitches were thrown into a net from a distance of 18.4 m. A rectangular target (0.64 m high x 0.38 m wide), with a small square in the middle, was secured onto the net. Three-dimensional Kinematic data were captured using a motion analysis system (Vicon Systems, Centennial, Colorado).

Seven Vicon T-20 cameras sampling at 300Hz tracked 32 retro-reflective markers placed directly on the skin according to the full-body plug-in gait model provided by Vicon. Specific anatomical locations for markers were secured bilaterally with 2-sided tape as follows: Third metacarpal, radial styloid, ulnar styloid, lateral humeral epicondyle, acromion, anterior superior iliac spine, posterior superior iliac spine, greater trochanter, lateral mid-thigh, lateral femoral epicondyle, lateral shank, lateral malleolus, posterior heel, and the first metatarsal head. One marker was placed at the manubrium, the mid-sternum, the inferior scapular angle of the throwing arm, the spinous process of the seventh cervical vertebra, and the spinous process the tenth thoracic vertebra. Four markers were secured on a headband (two anterior, two posterior) that each participant wore during data collection. Three-dimensional raw position data were processed using Vicon Nexus software. Gaps were interpolated and data were smoothed using a Woltring's quintic spline routine (Woltring, H.J., 1986).

Procedures

The order of the pelvic motion test and the hand velocity test was randomized. All participants performed both tests. Prior to testing, participants were allowed unrestricted time to warm up (~10-15 min) as they normally would before a practice or game.

Pelvic Motion Test

Using methods described previously (Chaudhari et al., 2011), participants performed a pelvic motion test where they transitioned from a bipedal stance to a unipedal stance by lifting and holding their kicking leg approximately 10 cm above the ground (Fig. 1). Participants repeated this test five times. Pelvic tilt (degrees) was recorded three-dimensionally using the Vicon system.

Pitching Hand Velocity Test

In addition to the warm-up, the participants performed 5 to 10 submaximal pitches to become comfortable pitching with reflective markers attached to their bodies. Once comfortable, pitchers were instructed to throw fastball pitches as fast and as accurate as possible from the wind-up position. They were asked to aim for the small square suspended in the middle of the target box. Participants continued throwing until 5 pitches were successfully recorded. A 30-60 second rest was allowed between pitches. The outcome measure of interest from this test was maximum hand velocity; obtained from the marker on the third metacarpal of the throwing hand.

Statistical Analysis

Five successful trials and five pelvic motion trials were used to compute the mean peak pitch velocity and pelvic tilt in the frontal and sagittal planes, respectively. Ninety-nine percent confidence intervals were used to interpret the correlation (Pearson's r) between bi-planar pelvic motion and hand velocity. The

intervals were predicted using the bootstrap procedure ($n=100$), which has shown to be viable in previous biomechanical research (Duhamel et al., 2004).

Results

Mean hand velocity was 21.87 ± 1.34 m/s. Mean AP tilt was $4.99 \pm 2.56^\circ$, and mean medial-lateral (ML) tilt was $8.27 \pm 1.79^\circ$. The mean variability (SD) in hand velocity within each participant was 0.41 ± 0.17 m/s. The mean variability (SD) in AP tilt within each participant was $1.66 \pm 0.90^\circ$. The mean variability (SD) in ML tilt within each participant was $1.47 \pm 1.15^\circ$. Based on ninety-nine percent confidence intervals, we observed a negative correlation between anterior-posterior pelvic tilt and hand velocity (99% CI: $-0.45 < r < -0.64$, See Figure 2) and a positive correlation between ML pelvic tilt and hand velocity (99% CI: $0.29 < r < 0.53$, See Figure 2).

Discussion

To our knowledge, this study is the first to examine three-dimensional pelvic motion in a test that closely resembles the wind-up phase of the pitching motion. We observed a median AP tilt of 7.89° , while Chaudhari et al. (2011) reported a median tilt of 7° which is quite similar given the magnitude of variability capable in the pelvic region. Indeed, our results support the general assertion that the pelvic region is a crucial component of the kinetic chain as evidenced by the relationships reported in Figure 2.

Optimizing control and position of the pelvis may contribute to acute and long term pitching success as evidenced by a significant increase in total innings pitched, a significant decrease in walks plus hits per innings pitched, as well as improvements in opponents batting average, strikeouts per inning and walks per inning (Chaudhari et al., 2011). The results of this present study imply that pelvic motion in the sagittal plane is negatively correlated with hand velocity, while motion in the frontal plane is positively correlated. Since ML pelvic motion during leg loading occurs in the same plane as the pitch itself, it is plausible that pelvic motion in this plane contributes to the overall effectiveness of the kinetic chain in the pitching motion, thus creating a faster pitch. Balance is thought to be essential to almost any athletic movement, so it stands to reason that pelvic motion in the sagittal plane may be detrimental because it shifts the center of gravity away from the base of support creating a balance deficiency (Marsh, Richard, Williams, & Lynch, 2004). Pitch performance may decrease because the center of gravity is no longer in the same plane as the pitch.

While not conclusive, this study does provide evidence that the pelvis plays an important role in pitching mechanics and performance. Practically speaking, pitchers and coaches may want to practice while focusing on pelvic position and motion. Coaches can give feedback regarding pelvic position, or pitchers can practice in front of a mirror or use video to view their own pelvic movements. Furthermore, strength and conditioning professionals may consider developing programs for pitchers that emphasize pelvic movements. Exercises that focus on the gluteal muscle group, and more specifically the gluteus medius,

may be beneficial due to its role in stabilizing the pelvis in a single-leg stance (Earl, 2005). Oliver and Keeley (2010) noted a need for greater gluteal control throughout the pitching motion due to the gluteal groups' likely influence on the entire pitch, and not trunk and pelvic control alone.

While our bootstrapped confidence intervals suggest a positive correlation between ML pelvic motion and hand velocity, and the opposite for AP motion, the limitations of this study must be taken into consideration. First, the small sample size used in the present study resulted in low statistical power. Additionally, all participants were college-aged, and only represented a small portion of the overall pitching population. However, the results do warrant future research investigating the role of the pelvis on pitching. Despite its limitations, we feel the results of this study add to the pitching performance literature and are important for future research.

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APPENDIX A

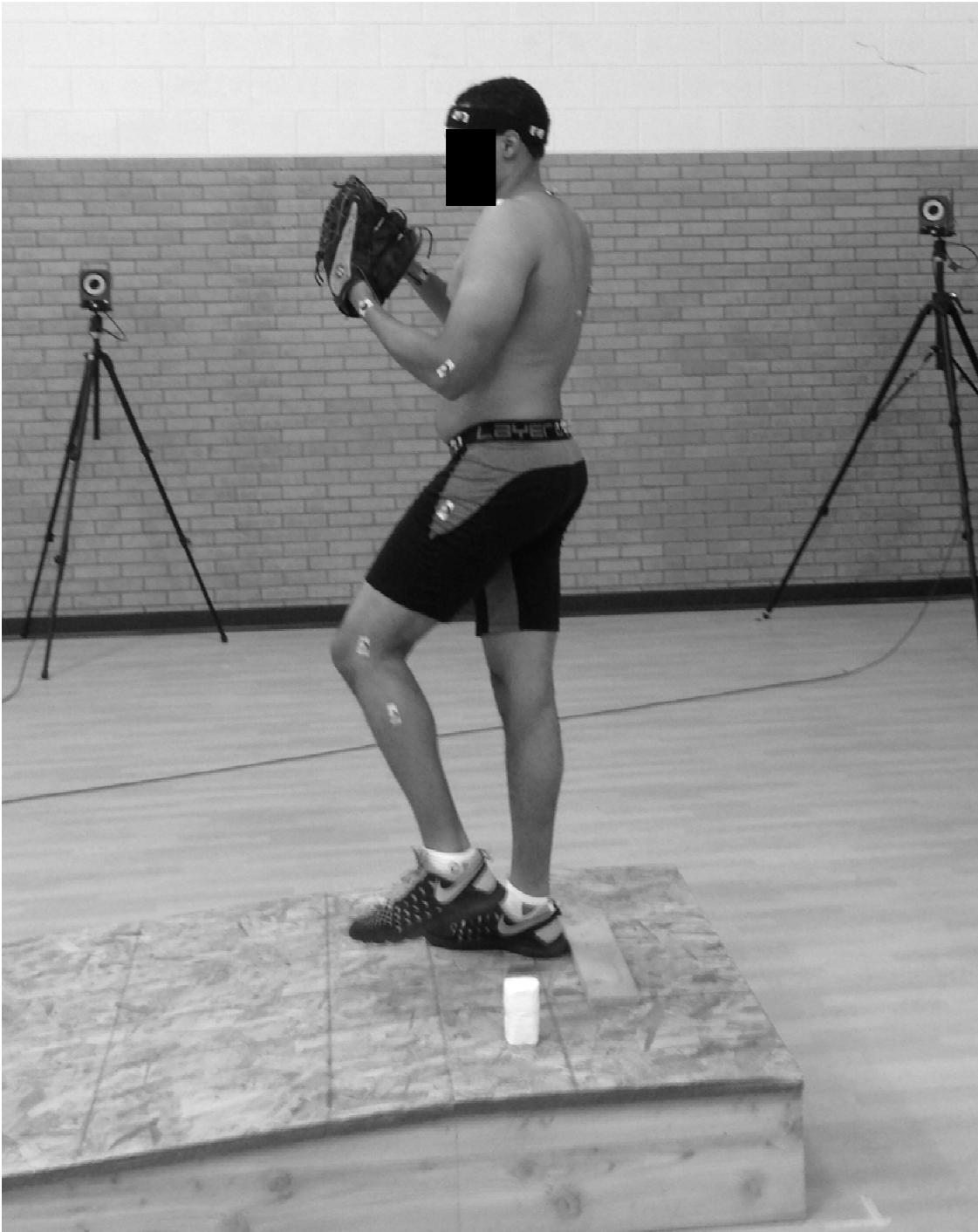


Figure 1. Subject performing the Pelvic Motion Test

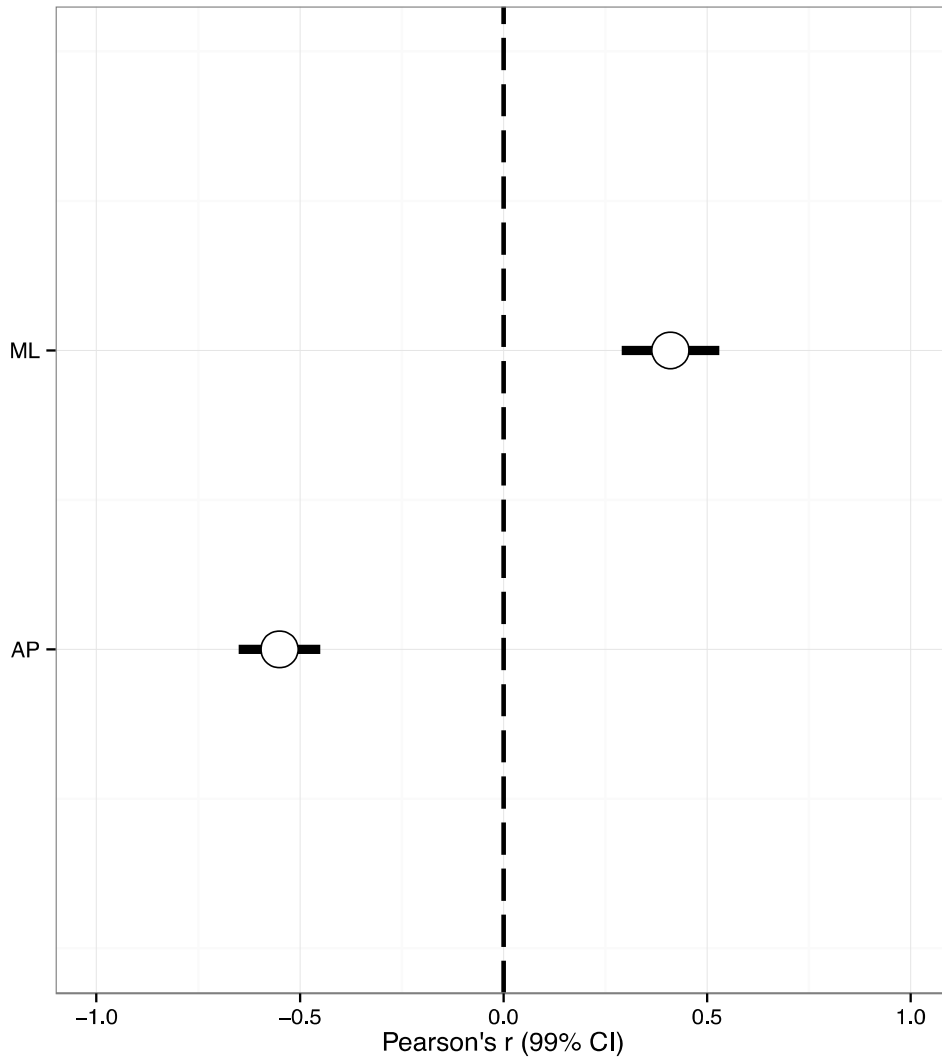


Figure 2. 99% Confidence intervals for anterior-posterior and medial-lateral pelvic motion