J Shoulder Elbow Surg (2019) 28, 330–334

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Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

The influence of lumbopelvic control on shoulder and elbow kinetics in elite baseball pitchers

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Background: Research has shown that diminished lumbopelvic control has a negative effect on pitching performance and can lead to more days on the disabled list. Despite the identified correlation between lumbopelvic control and injury, there is no research that has shown whether insufficient lumbopelvic control increases the force placed on the throwing arm.
Methods: Forty-three asymptomatic, National Collegiate Athletic Association Division I and professional minor league baseball pitchers participated. We measured the bilateral amount of anterior-posterior lumbopelvic tilt during a single-leg stance trunk stability test. We measured the shoulder and elbow kinetics of the throwing arm during the pitching motion using a 3-dimensional, high-speed video capture system. We used 2-tailed Pearson product-moment correlation coefficients (r) to determine the strength of the relationships between variables ($P < .05$).
Results: There were no significant relationships between the stride leg and any of the pitching kinetic variables ($r < 0.23$, $P > .14$). Similarly, there were no significant relationships between the drive leg and maximum shoulder distraction force, shoulder external rotation torque, or elbow distraction force ($r < –0.24$, $P > .13$). However, the drive leg did have significant relationships with both maximum shoulder horizontal torque ($r = 0.44$, $P = .003$) and elbow valgus torque ($r = 0.46$, $P = .002$).
Conclusions: Our results show that a relationship exists between lumbopelvic control of the drive leg and both shoulder horizontal torque and elbow valgus torque during the throwing motion. Because of these relationships, clinicians should consider incorporating lumbopelvic control training exercises to minimize the kinetic force placed on the throwing shoulder and elbow during the pitching motion.
Level of evidence: Basic Science Study; Kinesiology

Keywords: Core; stability; balance; joint force; throwing athlete; throwing mechanics

Baseball pitching requires a systematic sequence of movements that begins with the generation of power in the lower extremities. As the hips develop this power, it is transferred through the lumbopelvic region and finally to the throwing arm.[5] Because of the importance of this kinetic chain during the throwing motion, any disruption can result in decreased pitching performance and an increased risk of injury. The role of the lumbopelvic region during the pitching motion has been a source of increasing interest among players, coaches,

This study was approved by the Illinois State University Institutional Review Board before all data collection. This protocol was given the institutional review board number 2015-0269.

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https://doi.org/10.1016/j.jse.2018.07.015

clinicians, and researchers. Previous research has shown the high activity of the lumbopelvic muscles during the pitching motion,[11,13] as well as the large rotational force produced during a pitch.[12] Clinicians have hypothesized that the accumulation of force during the repetitive nature of baseball may be the cause of adaptations in the lumbopelvic region. Such adaptations include altered trunk[8] and hip range of motion,[10] as well as hip strength, among baseball pitchers.[10]

As new evidence continues to highlight the role of lumbopelvic muscle activity, range of motion, and strength during throwing, recent research has begun investigating the role lumbopelvic control plays among these athletes. From a performance perspective, Chaudhari et al[1] showed that pitchers with less lumbopelvic control produced more walks and hits per inning than those with more control. Similarly, pitchers with less lumbopelvic control have been shown to have an increased likelihood of spending more days on the disabled list than those with more control.[2]

Despite the identified correlation of lumbopelvic control with pitching performance and injury, no research has investigated whether insufficient lumbopelvic control increases the force placed on the throwing arm during pitching. The purpose of our study was to determine the strength of the relationships between lumbopelvic control and upper-extremity pitching kinetics in elite baseball pitchers. We hypothesized that as lumbopelvic control decreases, pitchers' joint force in the shoulder and elbow would increase during the throwing motion. Having a better understanding of the role that lumbopelvic control plays in the pitching motion may provide valuable information in the prevention, assessment, and treatment of the various shoulder and elbow injuries commonly sustained by baseball pitchers.

Materials and methods

Subjects

Forty-three elite baseball pitchers (age, 20.1 ± 2.3 years; height, 189.1 ± 6.1 cm; mass, 94.2 ± 10.8 kg) volunteered to participate in this study. Of these pitchers, 26 were from a single National Collegiate Athletic Association Division I collegiate baseball team and 17 were from various minor league levels (A-AAA) of a single professional baseball organization. All participants were asymptomatic at the time of testing. The exclusion criteria consisted of any recent upper- or lower-extremity injury (within 3 months) or any history of upper- or lower-extremity surgery.

Procedures

All testing occurred during a single session and was conducted in the biomechanics laboratory of a sports medicine and orthopedic surgery center. All participants provided informed consent as mandated by the university's institutional review board before testing. No testing was conducted after any conditioning workout or throwing session. For the collegiate pitchers, all tests were completed 2 months before the beginning of their fall season. The minor league pitchers completed all tests 2 months before the beginning of their spring training. The same investigators conducted all measurements throughout the study.

Pelvic control measurement

The Level Belt Pro (Perfect Practice, Columbus, OH, USA) was used to assess anterior-posterior lumbopelvic control. The Level Belt Pro consists of an iPod (Apple, Cupertino, CA, USA)–based digital level secured to a belt using hook-and-loop fasteners. To prepare the participant, the belt and attached iPod were secured around each participant's waist, covering the anterior and posterior superior iliac spines. For pelvic control testing, the "stride leg" was defined as the leg on the opposite side of the throwing arm that, during the throwing motion, is used to step or stride toward the intended target. Conversely, the "drive leg" was defined as the leg on the same side as the throwing arm and is used in pitching to push off the mound rubber and move the body forward toward the intended target.

Lumbopelvic control was tested using a single-leg balance movement. For this testing, subjects began standing with both feet shoulder width apart and their weight evenly distributed. They were then instructed to shift all their weight to the test limb and flex the non-test hip so that the leg was approximately 10 cm off the ground (Fig. 1). This position was held for 2 seconds; then, subjects returned to the starting position in a controlled manner while still maintaining all their weight on the test leg.[1,2] The anterior-posterior deviation of the pelvis from its starting position relative to the horizon was measured in degrees using the Level Belt Pro, and the largest peak absolute pelvic tilt from the starting position was recorded for analysis.[1,2] An investigator visually monitored each subject's position during testing to ensure correct motion was used. Subjects were not allowed to hold on to any objects for support or allowed to have their non-test limb touch the ground. If, at any time, the correct alignment or motion was not performed, the trial was ended and not used for analysis. The subject was then allowed to rest and repeat the test to ensure correct positioning and motion for all tests. The order of limb testing was randomized between participants, and the results were not shared with the participants, coaches, or medical personnel.

We assessed a priori intratester reliability of this lumbopelvic control assessment in 10 subjects (20 limbs). These subjects were not baseball players and did not have any previous injury or surgery. Each subject's lumbopelvic control was measured and then reassessed no more than 24 hours later. Good reliability (intraclass correlation coefficient, 0.88) and standard error of measurement (0.93°) were found for this assessment of lumbopelvic control.

Pitching kinetic measurement

All subjects performed their usual warm-up routines before pitching kinetic data collection. These warm-ups consisted of exercises such as light cardiovascular activity, static and dynamic stretching, throwing exercises, and pitching-specific exercises. After warm-ups, 26 reflective markers (Motion Analysis, Santa Rosa, CA, USA) were placed on various anatomic landmarks using a standard setup.[17-19] All subjects wore spandex shorts and no shirt to limit accessory marker movement.

After marker placement, each subject was provided time to become comfortable with throwing with the markers on and off an

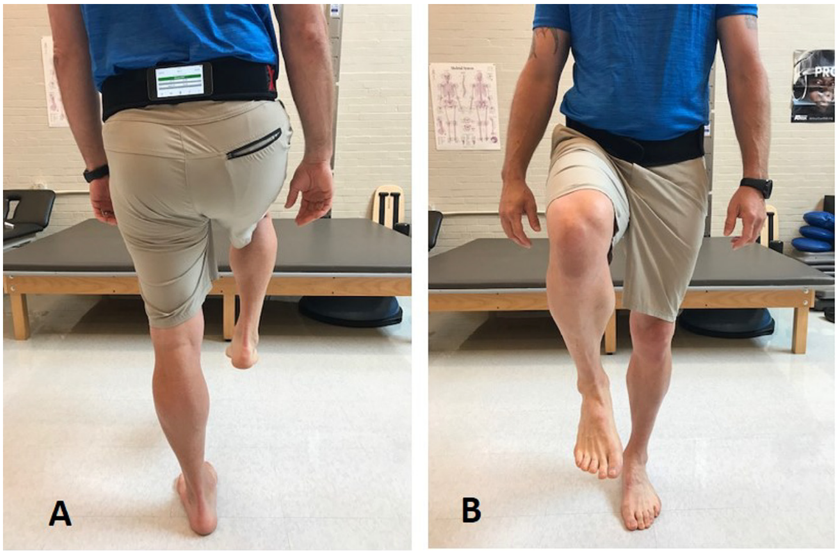

Figure 1 Lumbopelvic control measurement using single-limb stance test: posterior view (**A**) and anterior view (**B**).

indoor pitching mound measuring 2.7 m (length) × 2.5 m (width) × 0.3 m (height) (ProMounds ProModel Pitching Mound; ProMounds, Brockton, MA, USA). A home plate was positioned 18.4 m away with a live catcher positioned behind the plate. Five representative fastball trials were initially collected. The criteria for these representative fastballs included hitting the strike-zone target while using typical pitching mechanics that felt natural for each respective subject. Pitches outside of the strike zone and those that felt abnormal were excluded from data analysis. All pitch locations were monitored by an investigator standing behind the pitcher. A second investigator, positioned behind the strike-zone target, determined which throwing trials hit within the target and used a radar gun (Stalker Sport, Plano, TX, USA) to determine the 3 fastest pitches, which were used for data analysis.

All pitches were recorded using 8 electronically synchronized high-speed (240-Hz) Eagle digital cameras (Motion Analysis). The reflective markers were tracked using Expert Vision software (EVa, version 6.0; Motion Analysis), and 3-dimensional coordinate data were determined using the direct linear transformation method. Bilateral joint centers of the shoulders and elbows were estimated as previously described by Fleisig et al.[4] Coordinate data were filtered using a Butterworth fourth-order, zero-lag digital filter (cutoff, 10 Hz). Shoulder and elbow torques were calculated using the methods described by Feltner and Dapena.[3]

Statistical analysis

Two-tailed Pearson product-moment correlation coefficients were used to determine the strength of the relationships between variables (SPSS Statistics software, version 22; IBM, Armonk, NY, USA). The independent variables were stride leg and drive leg lumbopelvic control, whereas the dependent variables were maximum shoulder distraction force (percentage of body weight), shoulder horizontal abduction torque (percentage of body weight × height), shoulder external rotation torque (percentage of body weight × height), elbow distraction force (percentage of body weight), and elbow valgus torque (percentage of body weight × height). Findings were considered significant at an α level of $P < .05$.

Results

The lumbopelvic control values for the pitchers were 2.5° ± 1.6° for the drive leg and 2.5° ± 1.8° for the stride leg. These findings are similar to those of Chaudhari et al,[2] who used similar methods. The average ball velocity was 38.0 ± 1.8 m/s. Preliminary analyses were performed to ensure no violation of the assumptions of normality, linearity, and homoscedasticity occurred. The descriptive pitching kinetic characteristics can be viewed in Table I. There were no significant relationships between the stride leg and any of the pitching kinetic variables ($r < 0.23$, $P > .14$) (Table II). Similarly, there were no significant relationships between the drive leg and maximum shoulder distraction force, shoulder external rotation torque, or elbow distraction force ($r < –0.24$, $P > .13$). However, the drive leg did have significant relationships with both maximum shoulder

Table I Descriptive pitching kinetic characteristics

Pitching kinetic variable	Mean ± standard deviation
Shoulder distraction, % BW	115.1 ± 30.5
Shoulder horizontal abduction torque, % BW × HT	3.3 ± 1.1
Shoulder external rotation torque, % BW × HT	1.5 ± 0.5
Elbow distraction force, % BW	71.7 ± 23.2
Elbow valgus torque, % BW × HT	4.3 ± 1.3

BW, body weight; *HT*, body height.

Table II Relationships between stride leg lumbopelvic control and pitching kinetics

Pitching kinetic variable	*r*	*P* value
Shoulder distraction	−0.05	.77
Shoulder horizontal abduction torque	0.03	.87
Shoulder external rotation torque	−0.14	.39
Elbow distraction force	−0.12	.46
Elbow valgus torque	0.23	.14

Table III Relationships between drive leg lumbopelvic control and pitching kinetics

Pitching kinetic variable	*r*	*P* value
Shoulder distraction	0.13	.41
Shoulder horizontal abduction torque*	0.44	.003
Shoulder external rotation torque	−0.24	.13
Elbow distraction force	0.07	.66
Elbow valgus torque*	0.46	.002

* Statistically significant relationship.

horizontal torque ($r = 0.44$, $P = .003$) and elbow valgus torque ($r = 0.46$, $P = .002$) (Table III).

Discussion

Previous research has reported that decreased lumbopelvic control not only negatively affects pitching performance[1] but also is associated with injuries in baseball pitchers.[2] Despite these associations, no research to date has investigated the strength of the relationship between poor lumbopelvic control and increased force placed on the upper extremity during the pitching motion. The results of our study are the first to show that decreased lumbopelvic control is associated with increased shoulder horizontal abduction torque and elbow valgus torque.

The throwing motion requires precise coordination and activation of the muscles and joints from both the upper and lower extremities to maximize performance and minimize the risk of injury. During the pitching motion, power is generated in the lower extremity and transferred through the hips and trunk to the upper extremity via the shoulder and elbow and, finally, through the wrist and hand.[5] Previous research has shown that limitations in hip range of motion increase the various shoulder torques during a pitch.[9] Keeley et al[7] found that decreased stride length, increased pelvic tilt toward the throwing side, and increased pelvic axial rotation velocity all resulted in increased compressive force in the glenohumeral joint. Oyama et al[14] reported that pitchers with an altered trunk rotation sequence had increased shoulder external rotation angles and increased proximal force. These previous studies showed how altered lumbopelvic control can affect the pitching motion. The results of our study provide further support, showing that decreased lumbopelvic control increases the force placed on the shoulder and elbow during the pitching motion.

Although lumbopelvic strengthening has been suggested to improve power and subsequently performance during the pitching motion,[13] it may also be important in decreasing the force placed on the shoulder and elbow during the throwing motion. Because of the relationship between lumbopelvic control and upper-extremity kinetics found in our study, as well as the previously mentioned studies, we believe it is important for pitchers to incorporate specific training to address this control. As participants in our study flexed and extended their non-test hip during single-limb stance lumbopelvic control testing, the test leg was required to maintain balance and proprioception through proper control of the lumbopelvic region. This type of control is often regulated by the gluteus medius.[6] This is important to note because of the muscle's role during the throwing motion. Baseball pitchers and catchers require a large amount of gluteal muscle activation throughout the throwing motion.[11,15] The activity of the gluteus medius in the drive leg increases throughout the throwing motion, peaking during the arm acceleration phase.[15] Subsequently, there is a negative relationship between gluteus medius activity and the rate of pelvic rotation, indicating that the activity of this muscle provides significant pelvic stability during throwing.[11] On the basis of the relationship found in this study, clinicians should consider specific strengthening of the gluteus medius in an attempt to control the lumbopelvic region during the throwing motion, thereby potentially reducing stress to the upper extremity.

Despite the clear benefits of proper gluteal strength during the pitching motion, this strength, as well as good range of motion, cannot solely overcome poor lumbopelvic control to ensure proper mechanics.[16] The results of our study suggest that a standing single-limb stance lumbopelvic control motion, similar to our test motion, may be used as a corrective and training exercise when deficits are detected.

There are a few limitations of this study worth mentioning. First, our subjects were elite pitchers capable of pitching at high velocities and producing a large force during the throwing motion. Pitchers with less experience, such as youth pitchers, may produce different results. Second, despite the significant relationships found between drive leg lumbopelvic control and upper-extremity torques, there are still large amounts of variance that are not accounted for: 81% ($r = 0.44$) of the maximum shoulder horizontal torque and 79% ($r = 0.46$) of the elbow valgus torque during the pitching motion could not be completely explained through lumbopelvic control. Despite acknowledgment of other variables that contribute to increased shoulder and elbow torques in pitching, it is important to take note of the role that lumbopelvic control has in increased force in the shoulder and elbow. Therefore, we suggest that clinicians consider strengthening programs designed to improve pelvic control to reduce the force placed on the shoulder and elbow.

Conclusion

The results of our study show that as lumbopelvic control of the drive leg decreases, shoulder horizontal abduction torque and elbow valgus torque increase. These findings suggest that decreased lumbopelvic control and the subsequent increased kinetics may play a role in the large prevalence of shoulder and elbow injuries among pitchers. We suggest that lumbopelvic control be incorporated into preseason screenings as well as during injury prevention and rehabilitation programs for pitchers.

Disclaimer

The authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

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