Original Research

Kinematics of Shooting in High School and Collegiate Lacrosse Players With and Without Low Back Pain

Joseph G. Wasser,* BS, Cong Chen,* MS, and Heather K. Vincent,*† PhD, FACSM

Investigation performed at Department of Orthopaedics and Rehabilitation, University of Florida, Gainesville, Florida, USA

Background: Low back pain (LBP) and motion alterations can occur in athletes who engage in high-speed throwing motions. The relationship between LBP and shooting motion in lacrosse players is not yet known.

Purpose: To quantify the effects of LBP on key kinematic parameters of the lacrosse shot and determine the contribution of the severity of LBP on specific kinematic parameters of the shooting motion.

Study Design: Controlled laboratory study.

Methods: High school and collegiate players ($N = 24$) were stratified into 2 groups based on back pain symptoms (LBP or no pain). Three-dimensional motion capture of overhead throws was used to collect data on knee, pelvis, trunk, and shoulder kinematics as well as crosse stick (the stick capped with a strung net) and ball speed.

Results: Mean low back numeric pain rating scale (NRS_{pain}) score was 2.9. Knee flexion at ball release was greater in the LBP than no pain group, indicating a more bent knee ($P = .04$). The LBP group demonstrated less angular velocity transfer from pelvis to trunk than the no pain group ($P = .05$). Total range of motion of the pelvis and shoulders during the shot and follow-through were less in the LBP group than the no pain group ($83.6^\circ \pm 24.5^\circ$ vs $75.9^\circ \pm 24.5^\circ$, $P = .05$). Age- and sex-adjusted regression analyses revealed that the low back NRS_{pain} rating contributed 6.3% to 25.0% of the variance to the models of shoulder transverse rotation range of motion, trunk and shoulder rotation angular velocities, and knee flexion angle ($P < .05$).

Conclusion: LBP severity significantly contributes to trunk and shoulder motion restriction during lacrosse shooting. Inclusion of lumbopelvic and core training and prehabilitation programs for high school and collegiate players may reduce pain in affected players as well as help them to attain appropriate motion parameters and avoid secondary musculoskeletal injuries.

Clinical Relevance: This research identified a prehabilitation need in the understudied lacrosse population. Therapeutic strategies can be developed to strengthen the throwing motion, which could control mechanical loading patterns on the low back and minimize pain symptoms in players with chronic LBP.

Keywords: lacrosse; lumbar; biomechanics; motion analysis/kinesiology

Lacrosse continues to increase in popularity in the United States. Despite rising participation rates, the understanding of basic lacrosse mechanics and their contributions to injury is not widely known. Among the several actions in lacrosse play, a key motion is the shot. Shooting precision and mechanics are dependent on the appropriate muscle activation patterns, adequate rotation of the shoulders over the pelvis, and sequencing of peak body segment rotational velocity.[2,11,12,16,32] Like other overhead athletes, lacrosse players develop high ball speeds by generating initial forces at the start of the shot and transferring that energy along the kinetic chain to ball release.[21,32] There are several potential factors that can affect force development and timing of the mechanics, including musculoskeletal or joint pain. Alternatively, the high forces generated by the shooting motion itself may place mechanical stresses on the body and may contribute to the development of musculoskeletal pain or injury. The lumbar spine and associated musculature transfer energy of the throwing motion from the lower to the upper body via rapid rotation, and these structures are involved with the acceleration and deceleration of the

†Address correspondence to Heather K. Vincent, PhD, FACSM, Department of Orthopaedics and Rehabilitation, Division of Research, UF Orthopaedics and Sports Medicine Institute (OSMI), PO Box 112727, Gainesville, FL 32611, USA (email: vincehk@ortho.ufl.edu).

*Department of Orthopaedics and Rehabilitation, Division of Research, Interdisciplinary Center for Musculoskeletal Training and Research, University of Florida, Gainesville, Florida, USA.

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upper body during a shot.[12,32] This led to the following question: Are there specific motion characteristics of players with and without low back pain (LBP)?

Large evidence gaps exist with respect to the potential relationships between mechanical factors of lacrosse shooting and the presence or severity of LBP.[34] This is problematic because high school lacrosse surveillance data have revealed that back injuries occur at a rate of 60 to 80 cases per 1000 athletic exposures.[15] LBP may adversely affect motion by interfering with the transfer of energy from the lower body to the upper body. Peak angular velocities of the hip, trunk, and shoulders and timing of these peak velocities produced during the throw would be negatively affected by pain. Moreover, if the normal kinematic sequence and coordination is altered in a throwing activity, the forces produced in the throwing motion are transferred to distal body segments, which may lead to injury elsewhere.[33] Moreover, restrictions in rotation of body segments engaged in earlier phases of the shot (eg, pelvis or torso) may increase the mechanical demands to segments engaged later in the shot such as the upper arm. The first essential step toward understanding the relationship between LBP and shooting mechanics in lacrosse players is to characterize the difference in mechanics between players with and without LBP.

Therefore, the purposes of this study were to (1) determine the differences in key kinematic motion parameters of the lacrosse shot between players with and without LBP and (2) quantify the contribution of LBP to the variance of kinematic parameters of the lacrosse shot. We hypothesized that players with LBP would demonstrate differences in shot speed and rotational excursions of the pelvis and shoulder and that LBP would be a significant contributor to rotational range of motion of the shoulders and pelvis and peak angular velocities of the pelvis, trunk, and shoulders.

METHODS

Study Design

This study and its procedures were approved by University of Florida's Institutional Review Board, and all participants provided written informed consent.

Participants

Players were stratified into 2 groups based on the presence of any mild to moderate LBP: no pain and LBP (presence of LBP during shooting movement). A total of 24 lacrosse players were enrolled. Goalies were excluded from the analysis due to their different lacrosse equipment and less positional emphasis on shooting.

Characteristics

Participant demographics were self-reported. Height and weight were measured using a medical-grade scale. Participants completed a study-specific questionnaire that detailed their history of lacrosse play, which included sessions per week, seasons per year played, and current training sessions similar to that reported in other studies.[22] Moreover, leg lengths were measured for both left and right legs using a cloth tape measure. For arm lengths, testers measured the distance between the shoulder acromion and the radial styloid process, and for leg lengths, the distance between the anterior superior iliac spine and the medial malleolus was measured.

Muscle Strength and Endurance

Dynamic muscle strength and endurance were assessed using leg press, seated row, and a seated shoulder press machine (MedX). Maximal strength testing consisted of reaching a 1-repetition maximum (1RM) for each of the 3 machines. After a standard warm-up of light repetitions, the resistance was progressively increased until only 1 repetition could be performed with good form. Subjective rating of perceived exertion values from the participant were used to set the resistance loads for each exercise. After conducting the 1RM tests, participants were allowed to rest and recover until they were ready to complete the endurance tests. Endurance testing for the shoulder press and seated row consisted of performing as many repetitions as possible during 1 minute using a resistance load of 50% of their 1RM value.

Low Back Pain

LBP with movement was self-reported using an 11-point numeric pain rating scale (NRS_{pain}; 0 = no pain and 10 = worst possible pain). The NRS_{pain} measure is an established, well-accepted outcome for chronic conditions, as described in the Initiative on Methods, Measurement, and Pain Assessment in Clinical Trials.[9] This assessment is valid and reliable for assessing pain intensity[31] in otherwise healthy college-aged students and children.[10,26] Participants indicated that pain was a low-grade chronic pain that was not caused by traumatic injury but developed over time.

Lacrosse Shot Description

Mercer and Nielson[20] provided a detailed description of multiple phases of a lacrosse shot that has been simplified in our recent work.[30] Key phases related to the lacrosse shot were selected due to reliable reproduction in our motion analysis. Still images of these phases and the respective events are depicted in Figure 1, A and B. The images include the player and the crosse (the stick capped with a strung net). The 3 phases include the crank-back, acceleration, and follow-through (Figure 1). The crank-back is the preparatory movement that represents the wind-up that precedes the acceleration of the crosse stick. Immediately after crank-back, there is a drive forward with the lead foot. The lead foot plant initiates the acceleration phase. The acceleration phase involves increasing angular velocities of the body segments (pelvis, trunk, shoulders) and crosse to prepare for ball release. The ball release is

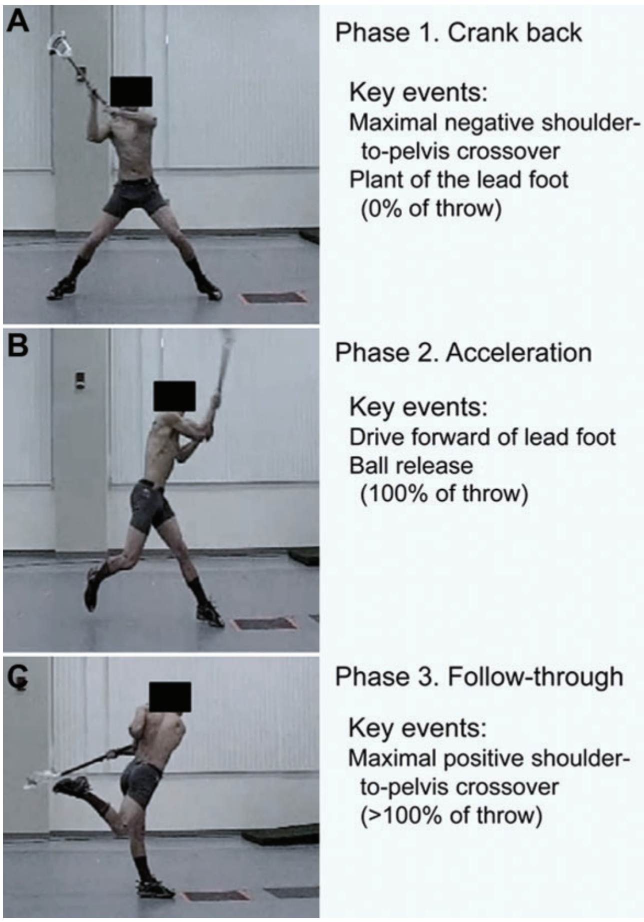

Figure 1. Key phases of the lacrosse shot used for this analysis. (A) Phase 1: Crank-back. The wind-up phase in which the shooting shoulder abducts and the trunk turns away from the target as the lead foot makes contact with the ground. (B) Phase 2: Acceleration. The phase in which angular velocities of the body segments (pelvis, trunk, upper arm about the shoulder) and crosse are increased to prepare for ball release. (C) Phase 3: Follow-through. The phase in which the maximal shoulder-to-pelvis crossover occurs toward the goal.

the event that terminates the acceleration phase and is used to define the end of the shot. The final phase of the lacrosse shot is the follow-through. This phase involves the relative trunk-to-pelvis separation motion and deceleration of the body segment rotations. The maximal shoulder-to-pelvis separation is the final event of the lacrosse shot. For our data analysis, we defined the starting event of the motion as the lead foot plant event (0%) and the final event of ball release as the end of the shot (100%). Follow-through occurred after ball release (>100% of the shot cycle).[1]

Motion Analysis Procedure

Motion was captured using a high-speed, 12-camera optical motion capture system (Motion Analysis Corp). The details of this technique have been previously described.[30] Data were captured at 200 Hz. Reflective markers were applied to the following anatomical landmarks: right scapula (offset), acromion processes, lateral epicondyles of the elbow, midway between the ulnar and radial styloid processes, third metacarpal, posterior superior iliac spines, anterior superior iliac spines, greater trochanters, lateral femoral epicondyles, lateral malleoli, heels, and the hallux. Markers and reflective tape were also placed on the stick end of the crosse, the crosse shaft, and the right and left sides of the net. Only reflective tape was used on a standard lacrosse ball (Figure 2).

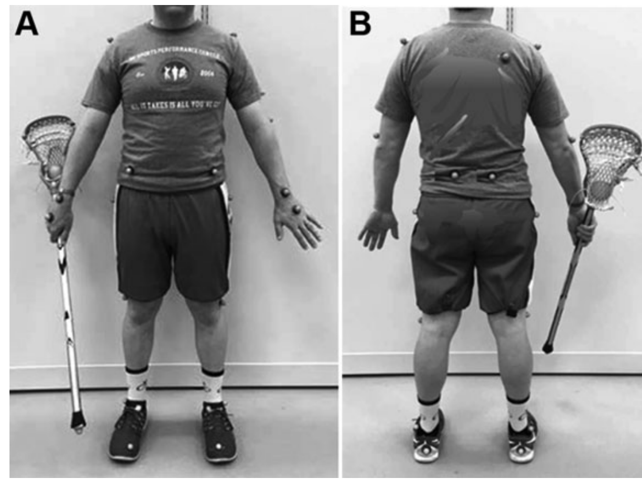

Figure 2. Experimental reflective marker placement used to capture the lacrosse shot motion. (A) Anterior view. (B) Posterior view.

After 5 minutes of throwing the ball as a warm-up, participants performed overhead shots with their dominant arm within the camera capture volume area. Participants used their own crosses. The dominant arm was defined as the arm with which the participant uses to write. The overhead shot was selected because it is a basic skill of the sport and is easily replicated by players. Each player was provided a set of standardized instructions to release the ball with as much speed and accuracy as possible, without compromising form for the sake of speed. Accuracy was defined as the ability of the ball to hit a marked area on a wall net that was the exact size of the goal. If the ball did not land in the goal target, the trial was excluded from analysis. The data from 3 trials were averaged to determine the average shooting motion.

Kinematic Measures

Specific kinematic events were expressed as a percent of the shot cycle using available software (MATLAB; Mathworks Inc). The software was used to calculate angular velocities of the pelvis, trunk, and shoulder at key shot cycle events; the relative orientation of the pelvis and trunk; and joint angles at foot contact and ball release. A summary of the kinematic measurements most relevant to back motion are provided in Figure 1. The shoulder-to-pelvis separation represents the intersegment linking between the pelvis and trunk, similar to the “X-factor” used in golf analysis,[3] and is associated with ball velocity.[7] This represents the coiling of the trunk that is capable of storing elastic energy[28] to be transferred to the forward motion and maximal crosse velocity and ball release. The differences in maximal angular velocities from pelvis to trunk, from trunk to shoulders, and from shoulder to the crosse were calculated to determine the sequential addition of rotational velocity to body segments and crosse before ball release.

These phases and events of the shot cycle are shown in Figure 1. In preparation for a shot, crank-back occurs, where the throwing arm abducts, and the trunk turns away from the target (phase 1). The crosse is then brought forward for acceleration of the shot (phase 2). Here, the throwing arm moves anteriorly toward the target. After ball release, the shoulder-to-pelvis separation continues into the follow-through (phase 3). This is the point of maximal shoulder-to-pelvis separation. The maximum angular velocity and the time at which the maximum angular velocity occurred were identified for the pelvis, trunk, shoulders, and crosse (expressed as percent of the shot cycle). The range of motion (ROM) values of knee flexion, shoulder rotation in the transverse plane, pelvis tilt in the sagittal plane, and pelvis rotation in the transverse plane were calculated from the difference between the maximal and minimal angular position values, from 0% to 100% of the shot cycle. Trunk anterior lean in the sagittal plane was calculated from the difference between the maximal and minimal angular position values, from –50% of the shot cycle to the end of follow-through. Finally, the total transverse ROM of the pelvis and shoulders was determined by summing the absolute value of crank-back and follow-through pelvis-to-shoulder separation angles.

Statistical Analysis

Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS version 23.0; IBM Corp). Data were managed using Research Electronic Data Capture.[14] Descriptive statistics were obtained to characterize the study groups (means and SDs, frequencies). After testing the skewness of the data, *t* tests were used to determine whether differences existed between the 2 groups of players (no pain, LBP) in the demographics, training volume and frequency, kinematic parameters, joint ranges of motion during the shot cycle, and ball speed. Chi-square (χ^2) tests were used to determine whether differences existed between the 2 study groups for categorical variables (sex, play position, level of play, LBP severity).

To determine whether the severity of LBP predicted shooting motion, variables, and ball speed in this population, hierarchical regression models were generated. The dependent variables were transverse ROM of the pelvis and shoulder; peak angular velocities of the pelvis, torso, and shoulders; and ball speed. The factors that likely contribute to variations in the dependent variables were entered into the models first (age and sex), followed by the severity of LBP as the final variable. A priori alpha levels were established at 0.05 for all statistical tests.

TABLE 1
Participant Characteristics of Lacrosse Players With and Without Low Back Pain[a]

	No Pain (n = 16)	Low Back Pain (n = 8)	*P*
Age, y	18.8 ± 4.1	18.1 ± 2.4	.671
Women, %	56.3	37.5	.490
Height, cm	174.3 ± 10.6	171.1 ± 9.4	.473
Weight, kg	70.1 ± 14.3	69.5 ± 11.8	.908
Lean mass, %	81.9 ± 5.8	77.5 ± 6.2	.096
Fat-free mass, kg	61.4 ± 17.5	54.0 ± 10.4	.261
Years of play	7.3 ± 4.7	6.6 ± 3.5	.733
Current sessions per week	3.0 ± 1.5	2.0 ± 1.5	.076
High school/collegiate athlete, %	56/44	50/50	.653
Position, %			
Attack	50.0	37.5	
Midfield	31.2	50.0	
Defense	18.8	12.5	.787
LBP severity, NRS_{pain} score	0.0	2.9 ± 2.2	.0001
Muscle strength (1RM), N·m			
Seated row	384.9 ± 144.9	354.4 ± 141.0	.607
Leg press	610.4 ± 103.2	614.3 ± 98.7	.925
Shoulder press	376.2 ± 162.6	327.3 ± 154.3	.462
Muscle endurance, repetitions/min			
Seated row	37.65 ± 7.4	33.1 ± 2.6	.006
Shoulder press	30.07 ± 6.1	29.7 ± 6.3	.887
Leg length, cm			
Right leg	89.8 ± 8.2	85.6 ± 10.4	.220
Left leg	89.8 ± 8.1	85.4 ± 9.8	.201

[a]Values are expressed as mean ± SD or percentage of the group. LBP, low back pain; NRS, numeric pain rating scale; 1RM, 1-repetition maximum.

RESULTS

Participant Characteristics

Table 1 provides participant characteristics. No significant differences were found between the no pain and LBP groups for any characteristic except for the NRS_{pain} score for back pain during shooting movement and the maximum reps on the seated row endurance test ($P < .05$).

Joint Angles and ROM

Table 2 provides the kinematic parameters generated during the lacrosse throwing motion from participants with and without LBP. There was a significantly greater knee flexion angle (bent leg) at ball release in the no pain group compared with the LBP group ($P = .04$). Compared with a straight vertical reference, a greater knee flexion angle represented a greater knee bend. There were no significant differences in the remaining joint angles, pelvic tilt, maximal shoulder abduction, and ROM values (transverse foot rotation, knee flexion, transverse pelvis, trunk lean, and transverse shoulder motion) during the shot cycle (all $P >$ .05). However, the total transverse ROM of the pelvis and shoulders from foot contact to follow-through was significantly less in the LBP group ($P = .05$).

TABLE 2
Stride Length, Joint Angles, and Range of Motion Generated During a Lacrosse Shot[a]

	No Pain (n = 16)	Low Back Pain (n = 8)	*P*
Stride length, m	0.94 ± 0.17	0.94 ± 0.15	.94
Stride-to-height ratio	0.53 ± 0.08	0.54 ± 0.08	.77
Joint angle, deg			
Lead foot angle at foot contact	25.5 ± 26.2	24.7 ± 20.6	.93
Lead foot angle at ball release	22.0 ± 19.4	16.0 ± 21.1	.49
Knee flexion angle at foot contact	163.9 ± 11.4	164.3 ± 5.9	.92
Knee flexion angle at ball release	160.6 ± 8.4	151.1 ± 13.0	.04[c]
Pelvic tilt at foot contact	20.2 ± 6.8	19.3 ± 4.9	.48
Pelvic tilt at ball release	26.2 ± 6.8	22.8 ± 5.1	.23
Trunk lean at ball release	12.4 ± 11.2	12.0 ± 13.3	.94
Maximal shoulder abduction	50.8 ± 18.6	53.9 ± 23.1	.72
ROM, deg			
Transverse lead foot rotation	3.5 ± 8.9	8.7 ± 14.0	.27
Sagittal knee flexion	22.5 ± 7.4	24.2 ± 11.4	.64
Transverse pelvis	63.8 ± 25.5	53.5 ± 32.1	.41
Sagittal trunk lean	32.8 ± 11.1	31.5 ± 17.1	.82
Transverse shoulder	94.4 ± 27.9	73.3 ± 43.6	.17
Total pelvis and shoulder[b]	83.6 ± 24.5	75.9 ± 24.5	.05[c]

[a]Values are expressed as mean ± SD. ROM, range of motion.
[b]Additive ROM in the transverse plane from foot contact to follow-through.
[c]Statistically significant difference between groups ($P \leq .05$).

TABLE 3
Relative Shoulder and Pelvis Rotation and Maximal Angular Velocities During a Lacrosse Shot[a]

	No Pain (n = 16)	Low Back Pain (n = 8)	*P*
Shoulder-to-pelvis separation			
Crank-back, deg	–30.7 ± 12.1	–28.5 ± 15.5	.69
Follow-through, deg	52.9 ± 20.1	46.5 ± 16.4	.44
Maximal angular velocity			
Pelvis, deg/s	534 ± 166	428 ± 179	.16
Trunk, deg/s	677 ± 198	515 ± 253	.05[b]
Shoulders, deg/s	898 ± 257	700 ± 316	.11
Crosse, deg/s	1570 ± 428	1345 ± 441	.24
Incremental change in angular velocity			
From pelvis to trunk, deg/s	151 ± 77	87 ± 83	.05[b]
From trunk to shoulders, deg/s	185 ± 76	240 ± 85	.14
From shoulders to crosse, deg/s	645 ± 191	671 ± 281	.81
Ball velocity, km/h	103.3 ± 24.7	90.6 ± 7.2	.30

[a]Values are expressed as mean ± SD.
[b]Statistically significant difference between groups ($P \leq .05$).

Relative Shoulder-to-Pelvis Crossover, Angular Velocities, and Timing

Table 3 provides the magnitude of the shoulder-to-pelvis separation and the values of peak pelvis, trunk, and shoulder angular velocities during a shot. Maximal trunk angular velocity was lower in the LBP group compared with the no pain group ($P = .05$). While there was an incremental increase in maximal angular velocities from pelvis to the crosse in both groups during the shot, the LBP group demonstrated less increase than the no pain group ($P = .05$). No statistical differences were found between players with and without LBP with respect to the timing of peak angular velocities of the pelvis, trunk, and shoulder during the shot (Table 4).

TABLE 4
Temporal Patterns of Maximal Segmental Angular Velocities During a Lacrosse Shot[a]

	No Pain (n = 16)	Low Back Pain (n = 8)	*P*
Pelvis, %	56.4 ± 28.7	62.6 ± 16.4	.60
Trunk, %	71.7 ± 16.9	78.2 ± 18.3	.39
Shoulders, %	80.4 ± 12.2	83.4 ± 21.4	.66

[a]Values are expressed as mean ± SD percentage of the shot cycle.

Regression Analyses

Our second aim was to quantify the contribution of LBP severity on the statistical variance of specific shooting kinematics (rotational motion of the pelvis and shoulders; peak angular velocities of the pelvis, trunk, and shoulder; knee flexion angle at ball release; and ball speed). Separate regression models were created for each kinematic variable. The results of these age- and sex-adjusted regression models are shown in Table 5. LBP severity contributed 6.3% to 7.9% of the variance to the models for transverse shoulder ROM and trunk and shoulder peak angular velocity at ball release (all $P < .05$). A striking finding was that LBP severity contributed 25% of the variance to the model for knee flexion at ball release ($P = .010$). For every 1-point increase in LBP severity, there was a 2.9° increase in knee flexion. The *B* coefficients indicated that the greater the LBP severity, the lower rotational ROM of the shoulder, the lower the peak angular velocities of the trunk and shoulders, and the stiffer the knee at ball release.

DISCUSSION

To our knowledge, this is the first examination of the relationship between LBP and shooting performance in lacrosse players. While many kinematic parameters of motion were similar between participants with and without LBP, those with chronic mild to moderate pain shot the lacrosse ball with greater knee flexion and slower peak trunk angular velocities. There was less incremental increase in angular velocities from pelvis to trunk in players with pain. LBP severity significantly contributed to several kinematic variables, including trunk and shoulder peak angular velocities and knee flexion at ball release. There are 2 possible interpretations of these findings: (1) the trigger of back pain may cause players to self-restrict high-speed rotation of segments that may exacerbate pain or (2) the motion itself over time caused the pain to develop. While this study was not able to measure pain onset longitudinally, the first possibility is explored.

TABLE 5
Hierarchal Regression Analyses for Kinematic Parameters of a Lacrosse Shot[a]

Parameter	R	R^2	R^2 Change	Significant F	B (95% CI)[b]
Pelvis rotation ROM in transverse plane	0.809	0.654	0.008	.52	–1.4 (–5.7 to 3.0)
Shoulder rotation ROM in transverse plane	0.851	0.723	0.063	.05[c]	–16.2 (–33.1 to 0.6)
Peak angular velocity, pelvis	0.812	0.659	0.037	.15	–18.5 (–44.6 to 7.6)
Peak angular velocity, trunk	0.834	0.696	0.079	.03[c]	–34.5 (–66.9 to –1.9)
Peak angular velocity, shoulder	0.840	0.706	0.069	.04[c]	–41.4 (–81.4 to –1.4)
Knee flexion angle at ball release	0.644	0.415	0.250	.01[c]	–2.9 (–5.1 to –0.8)
Ball speed	0.865	0.748	0.024	.17	–1.5 (–3.7 to 0.7)

[a]Each line represents a different regression model. Each model entered in age and sex first, and then the severity of low back pain was entered in as the final variable. ROM, range of motion.
[b]*B* coefficient is unstandardized.
[c]Significant contribution of low back pain to the variance of this parameter ($P < .05$).

Our findings are in partial agreement with other high-speed rotational sports that involve long lever arm equipment, such as golf or tennis, or that involve similar sequences of angular velocities from the pelvis, trunk, shoulder, and lever arm (eg, golf club, tennis racquet). Studies of golf swing motion demonstrate that players with symptomatic LBP used more lateral side bending on the backswing and had trunk flexion velocities during the downswing that were 2 times slower than players without pain.[18] During neutral stance, the golfers with pain had less trunk rotation during the swing than players without, indicating that the relative spine rotation was elevated during the backswing. Tsai et al[28] reported minimal differences in trunk kinematics. Biomechanical studies of tennis players also revealed minimal motion differences between players with and without LBP. In 1 study of tennis players (N = 21), serving kinematics were characterized by greater lateral pelvic tilt, lower lumbar and pelvic ROM, and anterior pelvic tilt in players with LBP compared with healthy players. Peak knee and hip flexion angles did not differ, but time to peak knee extension was earlier in players with and without LBP.[4] In contrast, Campbell et al[5] found that mean values of forehand or backhand groundstroke motion parameters did not differ in adolescent players with pain (N = 7) compared with those who had no pain (N = 12).

Pain may change the normal muscle activation of the muscles of the trunk that control the amount of spine rotation and rotational velocity. For example, LBP causes continual activation of the mulitifidus and longissimus muscles during axial rotation, which allows these muscles to then act as stabilizers.[17] LBP may also increase pelvic stiffness and thereby negatively affect the transfer of angular rotational velocities to the trunk further up the kinematic chain.[27] Our data support this possibility, as the LBP group had smaller incremental velocity from trunk to pelvis compared with the no pain group. Shooting motions require effective coordination of the timing and angular velocities of the proximal to distal segments to optimize ball speed. Variations in the timing or velocities can disrupt coordination and reduce performance.[29] Here, the timing of these velocities were not different, but the maximal angular velocities of the trunk were significantly lower during a throwing motion in participants with LBP. Additionally, total pelvis and shoulder ROM was significantly lower, suggesting that pain may not disrupt motion timing but rather induce a guarding effect on the lumbopelvic region restricting motion, which subsequently restricts angular velocities.

A striking finding was that greater low back NRS_{pain} scores were related to a greater knee flexion angle (more knee bend). An interpretation of this finding is that bending more at the knee can provide additional stabilization during spine rotation in players with LBP. Limited evidence from lacrosse, softball, and tennis players shows that the coactivation of lower extremity muscle groups (biceps femoris, rectus femoris, gastrocnemius) and the core (rectus abdominis, external obliques, and lumbar erector spinae) is essential for stabilization of the lower body as the upper body rotates over the pelvis.[6,21,23] LBP-related lumbar muscle strength deficiencies may foster greater knee flexion to improve the base of support during the throw. On the other hand, a secondary proposed reason for greater knee flexion (bend) is to allow a safe dissipation of linear forces. For many overhead sports, trunk flexion allows for the dissipation of forward linear motion, but with restricted lumbopelvic motion, a secondary compensation of knee flexion may allow for these linear forces to safely dissipate, similar to a follow-through. Additional research of the timing and magnitude of the lower extremity and core muscle activation in players with and without LBP would address this issue and provide therapeutic muscle targets for rehabilitation specialists and trainers who work with lacrosse players.

Strengths and Limitations

Some limitations and strengths of this study deserve comment. It is not yet clear whether mechanical deficiencies caused LBP or whether preexisting LBP changes the mechanics of the lacrosse throw. Dynamic strength values or endurance did not differ between the 2 groups, but we cannot rule out possible differences in muscle activation patterns that could overload the low back. Additional study of the electromyography patterns of the core and lower extremity muscles during the shot would be insightful. Other research groups indicate that sport motions that involve segmental rotations at the end of the ROM at high velocities may be an underlying mechanism for pain.[4,5] Epidemiological evidence suggests that exposure to high-velocity throwing or asymmetric loading sports over a lifetime or amount of practice contributes to the development of LBP.[8,13,19,24,25] Additional prospective injury tracking simultaneous motion analysis would help address this question. A larger sample size of lacrosse players would permit stratification of LBP presence and severity among positions and training volume. An important point is that these motions were captured in a laboratory setting without the presence of game conditions such as defenders, time pressure, or throwing on the run. These real-time factors may increase the "stakes" of each shot and may increase the risk for injuries to occur.

CONCLUSION

Lacrosse players with LBP have slower peak trunk angular velocities and greater knee flexion during a shot motion than players with no pain. Training and prehabilitation programs may be targeted to the lumbopelvic and core regions to help players with LBP maintain lacrosse shot motions and minimize or abolish pain. Future research should include prospective longitudinal research tracking LBP and throwing motion through a season to determine the relationship of pain onset to mechanics in this population.

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