

Original Research

Dynamic Functional Ability in Lacrosse Players in Relation to Development of Sport-Related Onset of Musculoskeletal Pain

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Background

Unlike other sports, the relationship between performance deficits and pain/injury in lacrosse players has not been well-investigated.

Purpose

The purposes of this study were to: 1) determine whether age and sex differences exist in dynamic physical function tests and drop jump performance among lacrosse players, and 2) determine whether pre-seasonal physical function scores predict onset of either lower extremity or low back pain over time.

Study Design

Prospective observational study.

Methods

Lacrosse players (N=128) were stratified into three groups: 12-14.9 yrs, 15-18 yrs and >18 yrs. Thomas test (hip flexibility), Ober's test (iliotibial band tightness), and Ely's test (rectus femoris tightness) were performed. Landing Error Scoring System (LESS) scores were collected while players performed drop jumps. Sagittal and frontal plane movement from 2D video during single and double legged squats was assessed. Musculoskeletal pain symptoms or injury were tracked for six months. Age bracket, sex and physical function scores were entered into logistic regression models to determine risk factors that predicted onset of lower extremity pain and low back pain onset.

Results

LESS scores and single-leg squat movement quality test scores were lowest in the 12-14.9 yr groups and highest in the >18 yr group (all $p < 0.05$). Single leg squat performance score increased the odds risk (OR) for lower extremity pain (OR=2.62 [95% CI 1.06-6.48], $p = .038$) and LESS scores elevated risk for low back pain onset over six months (OR = 2.09 [95% CI 1.07- 4.06], $p = .031$).

Conclusions

LESS scores and single legged squat performance may help identify lacrosse players at risk for musculoskeletal pain or injury onset. Detecting these pertinent biomechanical

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errors and subsequently developing proper training programs could help prevent lower extremity and low back pain onset.

Level of Evidence

III

INTRODUCTION

According to participation reports compiled by the NCAA, Lacrosse has been one of the fastest-growing American sports of the 21st century.¹ From 2000-01 the number of women's and men's teams had nearly doubled to 483 teams with a total of 11,375 athletes in 2015-16. Progressively greater numbers of younger players have participated in the sport and high school program growth has paralleled collegiate trends. In 2001, there were 938 schools with boys' lacrosse teams across 22 states and 783 schools in 21 states for girls' teams. In the 2021-22 academic year, the sport expanded into four new states for boys and six new states for girls.²

Epidemiological lacrosse studies indicate that acute injuries commonly occur in the sport, but chronic, non-contact musculoskeletal pain and chronic injuries also manifest.^{3,4} Depending on the nature of the injury, both types can contribute to time loss.^{4,5} As many as 28%- 40% of reported injuries do not require time away from the sport.^{6,7} While pain or chronic injury may not keep a player off the field, the presence of chronic pain may interfere with perceived ability to perform effectively, as also has been found among lacrosse officials.⁸ Overall, the incidence of chronic and acute injury is greater in high school players compared to youth,³ and greater in males compared to females.⁹ The lower extremity is the primary area where most injuries occur, with emphasis on ankle, knee and hip/thigh.^{3,6,7, 10} Back/trunk pain prevalence ranges from 2.8%-14.2% of youth through collegiate-level players.^{3,9} Moreover, the incidence of severity of injuries has changed over time. Bano et al.¹¹ found that the rate of severe injuries among players aged 11-18 years has increased by 85.3% from 2000-2016.

For many sports, the overall prevalence of musculoskeletal injury increases around adolescence for both males and females.¹² As such, determination of player characteristics and physical functional deficits that contribute to onset of musculoskeletal pain and injury is important for prevention efforts and sport safety over the long-term. Functional performance deficiencies may contribute to the possible onset of lower body musculoskeletal pains and injuries as has been documented in other well-studied sports like soccer, basketball and volleyball.¹³⁻¹⁵ Deficits or asymmetries in lower extremity strength, flexibility (quadriceps, hamstring, iliotibial band), and dynamic functional tasks reflect movement competence.¹³ Since lacrosse incorporates fast speeds, sudden direction changes, rotational movements, and jump landings, functional deficits may contribute to aberrant mechanical loading and onset of pain or chronic injury.^{16,17} Unlike other sports, the relationship between performance deficits and pain onset in lacrosse players has not been well-investigated.

Therefore, the purposes of this study were to: 1) determine whether age and sex differences exist in dynamic physical function tests and drop jump performance among lacrosse players, and 2) determine whether pre-seasonal physical function scores predict onset of either lower extremity or low back pain over time. First, it was hypothesized that younger players (12-14.9 years) and females would score less favorably on dynamic physical function tests than older players ≥ 15 years and males, respectively. Second, it was hypothesized that worse scores during drop jump tests, single legged squats and double legged squats would be related to a higher odds risk of developing and lower extremity and low back pain over six months.

MATERIALS AND METHODS

This was a prospective observational study of male and female adolescent through collegiate lacrosse players. This study and its procedures were all approved by the University of Florida Institutional Review Board (IRB). Data were merged from two cohort studies of lacrosse players. Prior to participating in the research, all participants ≥ 18 years provided written consent, and all participants < 18 years provided written assent with parental consent. All procedures on human subjects were conducted in accordance with the Helsinki Declaration of 1975, as revised in 1983.

Players were recruited from various clubs and school teams in the North Florida region, using flyers, web advertisements, and word of mouth. Players were stratified into three age groups from adolescence through young adulthood: 12-14.9 years, 15-18 years and > 18 years. Age was self-reported. Height and weight were obtained using a medical-grade scale. Body mass index (BMI) was calculated as: $BMI = \text{body weight (kg)} / \text{height (m)}^2$. A study-specific survey was developed to determine key information about the lacrosse playing experience of each participant. The survey included questions about years of experience, current weekly frequency of lacrosse practice sessions or games, and the number of seasons played per year. Positions were categorized into offense (midfield, attack) and defense (including goalie).

A series of physical function exam tests, single leg squat and double leg squat motion tests were performed. The functional tests included the Thomas test to identify hip flexibility limitations, Ober's test for iliotibial band tightness, and Ely's test for rectus femoris tightness. A digital goniometer (Wixey® angle gage) was used to record flexibility (bilaterally) for each of the following tests.

Thomas' Hip Flexor Test. To conduct the test, the participant lay supine on a clinical table, with both knees brought to the chest. While keeping the back flat against the table, the participant dropped one leg into extension, followed by the knee dropping into flexion. The test is considered

positive for tightness of the one-joint hip flexors if the hip does not extend to 0 degrees.¹⁸ The Thomas test's intra-class coefficient (ICC) is 0.97 (95% confidence interval of 0.91–0.99).¹⁹

Ober's Iliotibial Band Test. Ober's test estimates the tightness of the iliotibial band.²⁰ The participant was positioned on their side, and the pelvis was fixed in line with the trunk. The knee was flexed to 90 degrees, and the leg was abducted as far as possible. The tester allowed gravity to pull down on the leg. The goniometer captured this angle, with horizontal as 0 degrees. This was considered a positive test if the hip did not fall into adduction upon release. Using inclinometers, previous investigators have found that healthy athletes' average hip adduction angle is -10.6 ± 9.6 degrees (where positive tests have an adduction angle of -0.3 ± 7.0 degrees).²¹ The ICC of this test is 0.90¹² and inter-tester agreement is high at 97.6%.²¹

Ely's Test. Participants lay prone on the clinical table to perform Ely's test.²² The participant was instructed to keep the hip stationary against the table and pelvis in a neutral position. One knee at a time was actively flexed, and the heel was brought toward the ipsilateral buttock. The knee joint angle was captured at this position. The test was considered positive for quadriceps tightness if the anterior hip of the flexed side flexed and pulled away from the table during the knee flexion.²² The ICC for this test ranges from 0.42–0.52 for pass/fail ratings depending on the tester, and 0.914 for goniometer readings at the final knee flexion position.²³

Single and Double Legged Squat Tests. The quality of single and double legged squat performance has been used in clinical and sport settings to identify athletes with good and poor movement patterns. Squat performance is related to higher injury rates in incoming collegiate Division 1 athletes.²⁴ All players wore their habitual shoes and received standard instructions for each test. Movements were captured on video from the frontal and sagittal planes for later analysis. For double legged squat, athletes were instructed to place their feet at shoulder width, hold their arms straight out in front of the body, and act as if sitting in a chair. After four to five practice trials, three trials were captured. For the single legged squat, players stood on one foot and, placed hands on their hips, and looked straight ahead. Participants were then instructed to squat to a comfortable maximum depth and return to standing. Four to five practice trials were permitted, and three were captured on video. Bilateral measures were captured. For both tests, one trained investigator, exercise physiologist with 15 years of functional testing experience, (HKV) scored the squat performance from the videos, using published criteria by Eckard et al.²⁴ Double and single legged squats were scored for 10 and 9 operational definitions, respectively. Errors for double legged squats included foot turnout, flat foot, valgus or varus knee, anterior trunk lean, low back arching or rounding, forward arms, heel lift of or weight shift. Single legged errors included flat foot, valgus or varus knee, trunk or hip shifting, balance loss, knee flexion <60 degrees, low back rounding, trunk flexion/rotation/side bend and hip drop/hike. The asymmetry score for the single legged squat

was determined from the absolute difference in scores between limbs.

Drop Jump Tests. The Landing Error Scoring System (LESS) scores, developed by Padua et al.²⁵ were obtained from each participant while performing drop jump maneuvers. The LESS is the sum of the landing technique errors that can be visually observed and documented. High-speed video capture (300 fps) jump tests were viewed in sagittal and anterior planes. Participants performed drop jump landing tasks, which included jumping from a 30-cm high box to a distance of 50% of their height away from the box. After standard instructions were provided, familiarization trials (between three and five were typically needed) were performed to ensure the task was done correctly. Trials were repeated if the participant did not: jump off the box with both feet, jump vertically and forward rather than horizontally to reach the target marked on the floor, land outside the target area on the floor, or produce a fluid jump motion.

Prospective Tracking of Musculoskeletal Pain Onset. Pain was collected at baseline, and at months two, four, and six through an initial survey and then with follow-up telephone calls. The operational definition for pain in this study was onset of non-contact musculoskeletal pain or injury in the low back or to the lower extremities that occurred during lacrosse that caused the player to seek medical care. If pain was present, pain severity was captured using the 11-point Numerical Pain Rating scale (NRS_{pain}), with anchors of 0 (no pain) to 10 (worst imaginable pain). The NRS_{pain} scale is a valid, reliable, and responsive outcome measure with established minimum clinically important difference values.²⁶ Pain was rated for the following sites: foot, ankle, leg, knee, thigh, hip and low back. If the participant sought medical attention for the pain and a medical diagnosis was known, this was also recorded.

Statistics: SPSS statistics software version 29.0 (IBM Corp., Armonk, NY, USA) was used for the analyses. Descriptive statistics were obtained to characterize the study groups (means, standard deviations [SD], frequencies). The normality of the data was confirmed before analysis. Ordinal characteristics values and study outcome scores (lacrosse training and experience, other sports played, LESS scores, squat quality ratings) were compared using Kruskal-Wallis tests. Chi-square tests (χ^2) were used to determine whether group differences existed for dichotomous variables (positive clinical functional exam tests, pain presence) by age or sex.

Logistic regression was used to determine the risk factors that predicted onset of noncontact lower extremity pain or low back pain. Factors first entered into the model were age bracket and sex, followed by LESS scores, single legged performance scores and double legged squat performance score. As a proxy for model fit, the Nagelkerke R^2 are because it is adjusted to achieve a maximum value of 1 and simplifies interpretation.²⁷ A priori alpha levels were established at 0.05 for all statistical tests.

Table 1. Characteristics of lacrosse players of different age brackets. Value are expressed as the number of cases and percent of group, or as means and \pm standard deviation (SD).

	Age Bracket (years)			p
	12-14.9 (n=24)	15-18 (n=53)	>18 (n=51)	
Age (yr)	13.8 \pm 0.6	15.8 \pm 0.6	21.1 \pm 2.7	<.001
Height (cm)	165.9 \pm 8.9	173.5 \pm 9.3	174.6 \pm 9.4	<.001
Weight (kg)	56.8 \pm 9.2	68.1 \pm 11.8	72.8 \pm 11.5	<.001
Body mass index (kg/m ²)	20.6 \pm 2.6	22.5 \pm 2.8	23.8 \pm 2.1	<.001
Female (#, %)	7 (29.2)	23 (41.8)	21 (38.9)	.545
Playing position (#, %)				
Offense	19 (79.2)	39 (73.6)	44 (86.3)	
Defense	5 (20.8)	14 (26.4)	7 (13.7)	.373
Weekly sessions (#)	2.3 \pm 1.4	3.7 \pm 1.9	3.7 \pm 2.3	.008
Years playing lacrosse (#)	3.4 \pm 2.3	6.5 \pm 2.0	10.0 \pm 2.8	<.001
Total sports played in last year (#)	1.4 \pm 1.1	1.5 \pm 2.0	1.3 \pm 1.6	.090

RESULTS

Table 1 displays the characteristics of the study participants across the different age groups (N=128; U12- collegiate). The number of weekly lacrosse sessions and total years playing lacrosse were greater among players 15-18 years and >18 years compared to the youngest group (both $p < 0.05$).

Table 2 provides the results of the clinical exam functional tests. None of these clinical test scores (Thomas test, Ober's test, Ely's test) differed among the three age groups. When compared by sex, a higher proportion of males had positive Ober's tests on the left limb than females ($\chi^2 = 4.007$; $p = 0.045$).

LESS scores by age bracket are presented in [Figure 1](#). LESS scores were lowest in the >18-year group and highest in the 12-14.9 year bracket ($p < 0.05$). When compared by sex, males scored higher than females, but this was not significantly different (4.2 ± 1.8 points versus 3.8 ± 1.9 points, respectively; $p = 0.361$). The quality scores for single and double legged squat movements are provided in Table 3. Right and left single legged squat quality scores in players aged 12-14.9 years were worse than players in the >18-year age group (both $p < 0.05$). When compared by sex, left leg single legged squat and double legged squat quality scores were worse in males than females (both $p < 0.05$).

The sites for onset of musculoskeletal pain across player age brackets are reported in [Figure 2](#). Over six months, the two most common sites for pain onset among all players were the knee and low back. The 12-14.9 yr age reported a higher prevalence of knee pain than other age brackets ($p < 0.05$). The pains or reported associated injuries if available were reported. These included metatarsal stress syndrome, patellofemoral pain, Iliotibial band pain, bilateral proximal hamstring pain, Achilles tendon or calf pain, ankle sprain, piriformis syndrome, plantar fasciitis, metatarsal bone and foot pain, quadriceps muscle strain, hip impingement syndrome, idiopathic hip pain, sacroiliac joint pain and Sever's disease flare.

Logistic regression results are shown in Tables 4A-B. After accounting for age bracket and sex, single legged squat quality scores were associated with an elevated OR for developing lower extremity pain over six months (4A; OR = 2.62 [95% CI = 1.06, 6.48], Nagelkerke $R^2 = 0.171$; $p = 0.038$). The LESS scores were associated with an elevated OR for low back pain (4B; OR = 2.09 [95% CI 1.07, 4.06], Nagelkerke $R^2 = 0.261$; $p = 0.031$).

DISCUSSION

The main findings of this study were that the youngest athletes demonstrated the worst performance scores with single-leg squats, and highest LESS scores of the three age groups. Male players in this sample produced worse scores on both single-leg and two-legged squats than females. Over six months, the risks for onset of lower extremity pain and low back pain were higher in players with worse single-leg squat and LESS scores, respectively. These findings suggest that suboptimal neuromuscular control might be a contributing factor to the onset of lacrosse-related musculoskeletal pain.

Directly comparable functional performance data in lacrosse are scarce. Accumulating evidence in other sports provides context to these findings, however. First, younger athletes (or less developmentally mature) may demonstrate more movement variability than older athletes. Among soccer players of varying ages (U14 to U20), younger players have lower postural stability in single-leg stance tasks and demonstrate more sway of the center of pressure.²⁵ Tuck jump landing scores have been reported to be worse among U11 than U18 soccer players.¹⁹ Another study showed that pre-teen (<12 years) athletes of varying sport backgrounds demonstrate more kinematic variability during drop jump tests than more mature athletes (≥ 12 years).²⁸ Among multisport youth and adolescents, single-leg squat performance scores were worst in the youngest and least physically mature athletes.²¹ Thus, the current findings are comparable to previous work relating younger age with

Table 2. Clinical exam functional test results in lacrosse players by age bracket (2A) and by sex (2B). Value are expressed as the number of cases and percent of group as positive tests.

	Age Bracket (years)			p
	12-14.9 (n=24)	15-18 (n=53)	>18 (n=51)	
A. Age Bracket (years)				
Thomas test (#, % positive); Hip Flexibility				
Right	2 (8.3)	3 (5.7)	1 (1.9)	.364
Left	1 (4.2)	1 (1.8)	0 (0)	.368
Ober's Test (% positive); IT Band tightness				
Right	0 (0)	2 (3.7)	6 (11.7)	.113
Left	1 (8.3)	2 (3.7)	1 (1.9)	.757
Ely's Test (% positive); Rectus femoris tightness				
Right	0 (0)	2 (3.8)	0 (0)	.187
0 (0)	0 (0)	1 (1.8)	1 (1.9)	.781
	Male (n=77)	Female (n=51)		
B. Sex				
Thomas test (#, % positive); Hip Flexibility				
Right	4 (7.8)	4 (2.0)		.696
Left	4 (7.8)	3 (6.0)		.627
Ober's Test (% positive); IT Band tightness				
Right	9 (11.7)	2 (8.3)		.224
Left	7 (9.0)	0 (0)		.045
Ely's Test (% positive); Rectus femoris tightness				
Right	4 (5.2)	1 (2.0)		.483
Left	4 (5.2)	2 (8.3)		.951

functional performance deficits. Concerning LESS scores, the youngest players produced the highest error scores compared to the older players, and this corresponded with the highest prevalence of new knee pain in this age group. The LESS scores here align with data from collegiate athletes, including lacrosse players, which range from two to nine errors.²² Strong hip and core musculature are essential for stabilizing the lower extremities, especially in lacrosse, which requires high running volumes, direction changes, and jumping. These hip flexor muscles are essential for controlled running, cutting, and landing biomechanics. Poor hip muscle control, especially in hip abduction, extension, and external rotation, predisposes athletes to knee valgus and potential lower-body musculoskeletal injuries, particularly in the knee.²³ Excessive knee valgus in athletes is related to a higher risk for knee ligament injury and chronic injuries like patellofemoral pain syndrome.²⁹

Multiple studies have highlighted the differences in sex in regards to LESS scores as well as single and double-legged squats. Meta-analyses of pooled data of a healthy population illustrated that females have higher LESS scores than males.³⁰ Specifically, during the drop jumps females are more prone to errors at initial contact in trunk flexion, medial knee position, medial knee displacement and total joint displacement.³¹ In regards to single leg squats, previous studies have shown that female athletes are more disposed to increased adduction and internal rotation at the

hips.³² Interestingly, the data from this study did not corroborate this as females were shown to have lower error scores with both single and double legged squats (left leg single squat $p=0.006$, double leg squat $p=0.007$). Whether this was due to the limited amount of female athletes included in the study remains unclear.

Performing jump landing tests and specific functional tests in lacrosse players could help identify athletes who may benefit from injury prevention strategies. Educating coaching staff, players, and care teams about safe mechanics of jump landings, strengthening core and hip musculature, and improving dynamic stability has the potential to prevent a variety of lower body injuries and knee ligament injury. Training programs can be implemented to address these biomechanical deficiencies, therefore, potentially decreasing their future risk of injury. USA Lacrosse, with MedStar Health, offers LaxFit, a standardized program that reduces these high-risk injuries, promotes athlete development, and improves performance.³³ Multicomponent preventative training programs that include plyometrics, strength, agility, flexibility, and balance can reduce injury rates, even for severe injury like rupture of the anterior cruciate ligament, as much as 75% upon completion of the 15-20 minute program two to three times per week.³⁴ Plyometric drop jump training has improved several performance metrics of on-field performance across youth and adolescent athletes.³⁵ The challenge of this initiative is

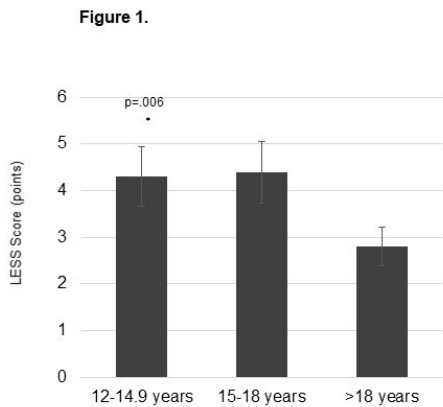


Figure 1. Landing error scoring system (LESS) values for lacrosse players across different age brackets. Values are means ± SD. * denotes different from the >18 year group at p<0.05.

widespread adoption and implementation of injury prevention programs across geographic areas.

There were limitations identified in this study. Cross-sectional design does not allow for cause and effect of these biomechanical deficiencies on injury onset. Future studies could use prospective data collection and injury surveil-

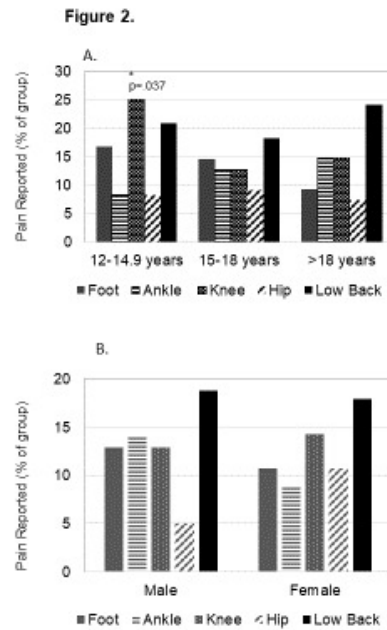


Figure 2. Prevalence of musculoskeletal pain reporting at the low back and lower extremity in lacrosse players over six months. Values are percent of the group.

lance over years of play to determine predictive relationships to the onset of new injury over the course of an athletic career. The physical function metrics are but a small sample of potential neuromuscular tests that can be used to screen athletes prior to the preseason. Future work could consider use of additional field screening tools or motion sensors that could produce better pain and injury predic-

Table 3. Single-leg and double-leg squat movement quality in lacrosse players of different age brackets (3A) and by sex (3B). Values are means ± SD. Higher scores represent a higher number of errors during the task.

	Age Bracket (years)			p
	12-14.9 (n=24)	15-18 (n=53)	>18 (n=51)	
A. Age Bracket (years)				
Single leg squat score (points)				
Right	2.2 ± 0.8 *	2.0 ± 1.1	1.7 ± 0.9	.001
Left	2.6 ± 1.3 *	1.9 ± 1.1	1.5 ± 0.8	.016
Interlimb asymmetry (points)	0.8 ± 0.6	0.8 ± 0.7	0.5 ± 0.5	.180
Double leg squat score (points)	0.9 ± 1.1	0.5 ± 0.6	0.5 ± 0.6	.307
Post hoc test: * different than >18 year group				
	Male (n=77)	Female (n=51)		
B. Sex				
Single leg squat score (points)				
Right	2.4 ± 1.2	2.0 ± 0.9		.212
Left	2.5 ± 1.2 *	1.8 ± 1.0		.006
Interlimb asymmetry (points)	0.6 ± 0.6	0.7 ± 0.6		.659
Double leg squat score (points)	1.1 ± 0.9 *	0.5 ± 0.7		.007
* different than females by p<.05				

Table 4. Regression models to predict onset of lower extremity musculoskeletal pain and low back pain over 6 months (pre-post season).

A. Lower extremity pain		
Predictor	Odds Ratio [95% CI]	p value
Age bracket		
12-14.9	reference	
15-18	1.39 [0.20-9.67]	.738
>18	0.97 [0.13 - 7.48]	.968
Sex		
Male	reference	
Female	0.38 [0.11 - 1.35]	.138
LESS Score (points)	2.09 [1.07 - 4.06]	.031
Single-leg squat test score (points)	1.20 [0.45 - 3.18]	.727
Two-leg squat quality score (points)	0.95 [0.32 - 2.79]	.307
B. Low Back Pain		
Predictor	Odds Ratio [95% CI]	p value
Age bracket		
12-14.9	reference	
15-18	0.21 [0.03 - 1.79]	.153
>18	2.37 [0.34 - 16.37]	.283
Sex		
Male	reference	
Female	3.68 [0.72 - 8.91]	.118
LESS Score (points)	2.09 [1.07 - 4.06]	.031
Single-leg squat test score (points)	1.20 [0.45 - 3.18]	.727
Two-leg squat quality score (points)	0.95 [0.32 - 2.79]	.922

tion models. Dynamic tools may include the Star excursion or Y-Balance tests, time to stabilization after drops or hops, single leg jumps and hops, tuck jumps and asymmetry between limbs on relevant tests – any of which may have potential to improve injury prediction capacity,⁵⁶ particularly if the athlete holds a cross in their hands. This is an area of strong need to help advance the field of injury predictions in lacrosse similar to that of other sports. The included population consisted of relatively fewer younger female participants, a demographic subgroup in need of additional research. A more robust documentation of previous training exposure/ experience would have provided insight into our measures' performance differences. Finally, previous concussion history was not considered, which may have affected physical function performance.

CONCLUSION

The results of this study indicate that jump landing LESS scores, single legged and double legged tests performed in developing lacrosse players show potential for identifica-

tion of those at risk for future lower extremity and back pain.

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CONFLICTS OF INTEREST

None to declare.

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