6-2018

Preseason Lower Extremity Functional Test Scores Are Not Associated With Lower Quadrant Injury - A Validation Study With Normative Data on 395 Division III Athletes

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ORIGINAL RESEARCH

PRESEASON LOWER EXTREMITY FUNCTIONAL TEST SCORES ARE NOT ASSOCIATED WITH LOWER QUADRANT INJURY – A VALIDATION STUDY WITH NORMATIVE DATA ON 395 DIVISION III ATHLETES

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ABSTRACT

Background: Preseason performance on the lower extremity functional test (LEFT), a timed series of agility drills, has been previously reported to be associated with future risk of lower quadrant (LQ = low back and lower extremities) injury in Division III (D III) athletes. Validation studies are warranted to confirm or refute initial findings.

Hypothesis/Purpose: The primary purpose of this study was to examine the ability of the LEFT to discriminate injury occurrence in D III athletes, in order to validate or refute prior findings. It was hypothesized that female and male D III athletes slower at completion of the LEFT would be at a greater risk for a non-contact time-loss injury during sport. Secondary purposes of this study are to report other potential risk factors based on athlete demographics and to present normative LEFT data based on sport participation.

Methods: Two hundred and six (females = 104; males = 102) D III collegiate athletes formed a validation sample. Athletes in the validation sample completed a demographic questionnaire and performed the LEFT at the start of their sports preseason. Athletic trainers tracked non-contact time-loss LQ injuries during the season. A secondary analysis of risk based on preseason LEFT performance was conducted for a sample (n = 395) that consisted of subjects in the validation sample (n = 206) as well as athletes from a prior LEFT related study (n = 189).

Study Design: Prospective cohort

Results: Male athletes in the validation sample completed the LEFT [98.6 (± 8.1) seconds] significantly faster than female athletes [113.1 (± 10.4) seconds]. Male athletes, by sport, also completed the LEFT significantly faster than their female counterparts who participated in the same sport. There was no association between preseason LEFT performance and subsequent injury, by sex, in either the validation sample or the combined sample. Females who reported starting primary sport participation by age 10 were two times (OR = 2.4, 95% CI: 1.2, 4.9; p = 0.01) more likely to experience a non-contact time-loss LQ injury than female athletes who started their primary sport at age 11 or older. Males who reported greater than three hours per week of plyometric training during the six-week period prior to the start of the preseason were four times more likely (OR = 4.0, 95% CI: 1.1, 14.0; p = 0.03) to experience a foot or ankle injury than male athletes who performed three or less hours per week.

Conclusions: The LEFT could not be validated as a preseason performance measure to predict future sports injury risk. The data presented in this study may aid rehabilitation professionals when evaluating an injured athlete's ability to return to sport by comparing their LEFT score to population norms.

Level of Evidence: 2

Keywords: Agility, college, epidemiology, functional test, lower quadrant

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Conflict of Interest / Declaration Statement
The authors do not have any conflict of interests to report

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INTRODUCTION

The lower extremity functional test (LEFT) consists of a series of 8 agility drills performed on a diamond shaped course (Figure 1).[1-3] The LEFT was originally designed as a functional test to qualitatively and quantitatively assess an athlete's ability to return to sport after a lower extremity injury.[1-3] Recently the LEFT has been assessed for its ability to discriminate injury risk in athletic populations.[4,5] In an initial prospective cohort study, female Division III (D III) athletes who completed the LEFT in 118 seconds or more (e.g., slower female athletes) were six times more likely to experience a thigh or knee injury during the season.[4] Slower females (LEFT score ≥ 118 seconds or more) experienced an initial (e.g., first in-season injury) time-loss lower quadrant (LQ = low back and lower extremities) injury rate of 4.8 per 1000 athletic exposures (AE).[5] Slower female athletes experienced a subsequent (e.g., any injury after the first in-season injury) time-loss LQ injury at a rate of 17.4 per 1000 AEs.[5] Interestingly, faster male D III athletes with a LEFT score of 100 seconds or less were three times more likely to experience a time-loss LQ injury and six times more likely to sustain time-loss foot or ankle injury.[4] The authors of the initial study hypothesized that faster males may have had a greater risk of injury due to having more exposure (e.g., more minutes devoted to practice or game) than slower males; however, this form of athletic exposure (e.g., tracking minutes played) had not been collected (note: exposure in that study was based only on participation during a practice or game and not on minutes played per event).[4]

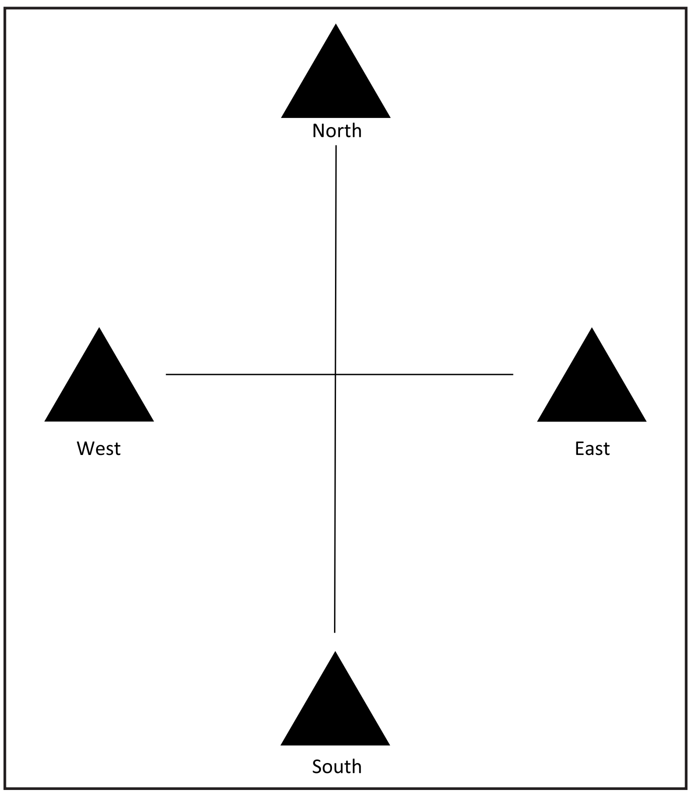

Figure 1. *Course Dimensions for the Lower Extremity Functional Test. Distance between the Northern and Southern triangles is 9.14 m (30 feet). Distance between the Eastern and Western triangles is 3.05 m (10 feet).*

A recent trend in sport science research is to attempt to identify athletes at risk for injury based on preseason measures of fitness.[6,7] Several functional performance tests (FPT), including the LEFT, have been assessed for their ability to discriminate injury risk in various athletic populations.[4,5,8-12] Many of the *initial* cohort studies that have assessed the potential predictive value of preseason FPT scores have reported significant relationships between suboptimal scores and future injury risk. However, these initial studies should be viewed with caution. Subsequent studies are warranted to validate the previously reported risk profiles. For example, Kiesel et al[12] reported a score of 14 or less on the Functional Movement Screen™ (FMS™) was associated with an 11-fold increased risk of professional football players experiencing a time-loss injury requiring a minimum of three weeks on the disabled list. However, since this initial report,[12] a majority of subsequent studies have failed to validate the original cutoff score (14 or less) and have failed to identify an alternate composite cutoff score for the FMS in order to discriminate injury risk in various sport populations.[13-20] Likewise, Plisky et al reported that female high school basketball players were 6.5 times more likely to have experienced a lower extremity injury when their composite score on the star excursion balance test (later developed into the Y-balance test) was less than or equal to 94 percent of their lower extremity (LE) length.[8] Subsequent studies, albeit with different sport populations, have reported different cutoff scores.[20,21]

As detailed in the prior paragraph, subsequent studies designed to validate risk profiles based on preseason FPT measures may not support initial findings. Thus, there is a need to conduct subsequent studies

to validate initial findings. The association between preseason LEFT scores and subsequent sport related injury has yet to be validated. The primary purpose of this study was to examine the ability of the LEFT to discriminate injury occurrence in D III athletes, in order to validate or refute prior findings. It was hypothesized that female and male D III athletes slower at completing the LEFT would be at a greater risk for a non-contact time-loss injury during sport. Secondary purposes of this study are to report other potential risk factors based on athlete demographics and to present normative LEFT data based on sport participation. It was hypothesized that those who spent less time training during the off-season, who started sport at an older age, and/or who had a prior history of injury would have a greater risk of injury.

METHODS

Participants

Two hundred and six Division III athletes (females = 104, males = 102) from one university were recruited to participate in this study and served as a validation sample. Inclusion criteria for this study was participation in a varsity level sport. Athletes were excluded from the study if: a) he/she was under the age of 18 or b) if he/she was restricted from full sport participation by their primary care provider or team athletic trainer at the start of the season. The validation sample consisted of athletes from the following sports: women's soccer = 35, men's soccer = 41, women's volleyball = 32, men's basketball = 15, women's track = 26, men's track = 40, women's tennis = 11, men's tennis = 6.

The validation sample (n = 206) combined with 189 athletes from a different D III university formed the "combined sample". The purpose of the combined sample was to a) assess injury risk profiles, per sex, in a large population of D III athletes and b) present normative data for the LEFT based on sex and sport participation. The initial sample of D III athletes (n = 189)[4] consisted of athletes from the following sports: women's soccer = 30, men's soccer = 19, women's cross-country = 5, men's cross-country = 6, women's volleyball = 26, men's wrestling = 14, women's basketball = 7, men's basketball = 14, softball = 10, baseball = 12, women's track = 2, men's track = 6, women's lacrosse = 17, women's tennis = 9, men's tennis = 12.

The Institutional Review Boards of George Fox University and Pacific University approved this study. Athletes provided informed consent prior to testing.

Procedures

Demographic measures, off-season training habits, prior injury history, and LEFT scores were collected from each athlete at the start of their sports preseason. Prior to performing the LEFT, each athlete provided the following information: age, years in university, age they started participating in their sport, and average weekly time devoted to training (in four categories: weightlifting, cardiovascular exercise, plyometric training, scrimmaging) during the six-week period of time prior to the start of the season.

Dynamic Warm-Up

Prior to performing the LEFT, each athlete performed a five-minute dynamic warm-up. This warm-up routine was performed to metabolically prepare the athlete for activity and to reduce the risk of injury.[22] Athletes were instructed to perform the following active movements at their own pace: forward walking, backward walking, forward lunging, backward lunging, and high knee marching.

Lower Extremity Functional Test Protocol

The LEFT is performed on a diamond shaped course: 9.14 m (30 ft.) in the North-South direction and 3.05 m (10 ft.) in the East-West direction (Figure 1).[1-3,23,24] Triangles, made with 0.305 m (1.0 ft.) strips of athletic tape, were placed at the end of each axis. The following agility drills are performed during the test in the following order: forward run, backward run, side shuffle, cariocas (Figure 2), Figure 8s, 45° cuts (plant outside foot), 90° cuts (plant outside foot), crossover 90° cuts (plant inside foot), forward run, and backward run.[1-3,23,24]

The athlete is positioned at the Southern triangle to start the test. The forward run (sequence: South – North – South) and backward run (sequence: South – North – South) are performed first at the start of the test and repeated at the end of the test. The remaining drills are performed both in a counter-clockwise and a clockwise direction. Consistent verbal instruction from an investigator is necessary due to the variety of skills performed and fatigue onset.[25]

Figure 2. *Athlete Demonstrating Carioca Progressing from the West Triangle toward the North Triangle.*

A researcher provided verbal instruction as to the next movement and its associated course direction as the athlete neared completion of a task. One trial of the LEFT was performed by each athlete. Time was recorded in seconds using a stopwatch. Test-retest reliability for the LEFT is 0.95 to 0.97.[24]

Injury Surveillance

The university's athletic training (ATC) staff documented all non-contact time-loss injuries to the LQ for all athletes. The operational definition of an injury was any musculoskeletal injury resulting from a non-contact injury mechanism to the lower quadrant (LQ) [categorized by region: low back, hip, thigh, knee, leg, ankle, or foot] that occurred during practice or competition that resulted in the athlete either failing to complete that day's event or requiring the athlete to miss a subsequent practice or competition.[25,26] The athletic trainers also provided athletic exposure data. In this study one athletic exposure was equal to participation in one practice or one game.

Statistical Analyses

A minimum of 67 subjects per sex, based on an *a priori* calculation, were needed to identify statistically significant associations between LQ injury and LEFT measures for the validation sample. Descriptive statistics (means $\pm$ SD) were calculated for demographic information, off-season training habits, and LEFT scores. Independent *t*-tests were utilized to compare means for demographics, training habits, and LEFT scores between sexes within the validation sample. Independent *t*-tests were also utilized to compare means between sexes within the combined sample for demographics, training habits, and LEFT scores. Mean ($\pm$ SD) LEFT scores were calculated, using data from the combined sample, and presented by sex for each sport. Independent *t*-tests were utilized to compare mean LEFT scores between sexes by sport. The PI collected injury records on a weekly basis from the ATC team.

Cutoff Scores

Multiple receiver-operator characteristic (ROC) curves (by sex) were created in order to identify potential cutoff scores that maximized sensitivity and specificity for demographic information, off-season training reports, and LEFT scores [Note: separate ROC curves analyzing LEFT scores were created for both the validation sample and the combined sample. The additional ROC curve analyses for demographic and training variables were only created using the combined sample]. Analysis of ROC curves for the validation sample failed to identify a cutoff score for the LEFT; thus, previously reported cutoff scores for the LEFT were used for regression analysis.[4] A majority of the ROC curves for the combined sample failed to identify a cutoff score for numerous variables; however, the category "age starting sport" was significant for "all LQ injuries" and "thigh or knee injuries". For female athletes in the combined sample, the area under the curve associated with all LQ injuries was 0.66 (95% CI: 0.57, 0.76) (Figure 3a) and the area under the curve associated with thigh or knee injuries was 0.66 (95% CI: 0.55, 0.77) (Figure 3b). All other measures were dichotomized based on either mean scores from the combined sample population or previously reported cutoff scores (for off-season training variables).[27] Univariate logistic regression was performed to calculate odds ratios (OR) and 95% confidence intervals (CI). Logistic regression was performed for both the validation sample (per sex) and for the combined sample (per sex). Risk profiles were calculated based on region of the body injured: 1) all injuries (e.g., all LQ injuries), 2) thigh or knee injuries, and 3) foot or ankle injuries. Data analysis was performed using SPSS Statistics 23 (Chicago, IL) with the alpha level set at 0.05.

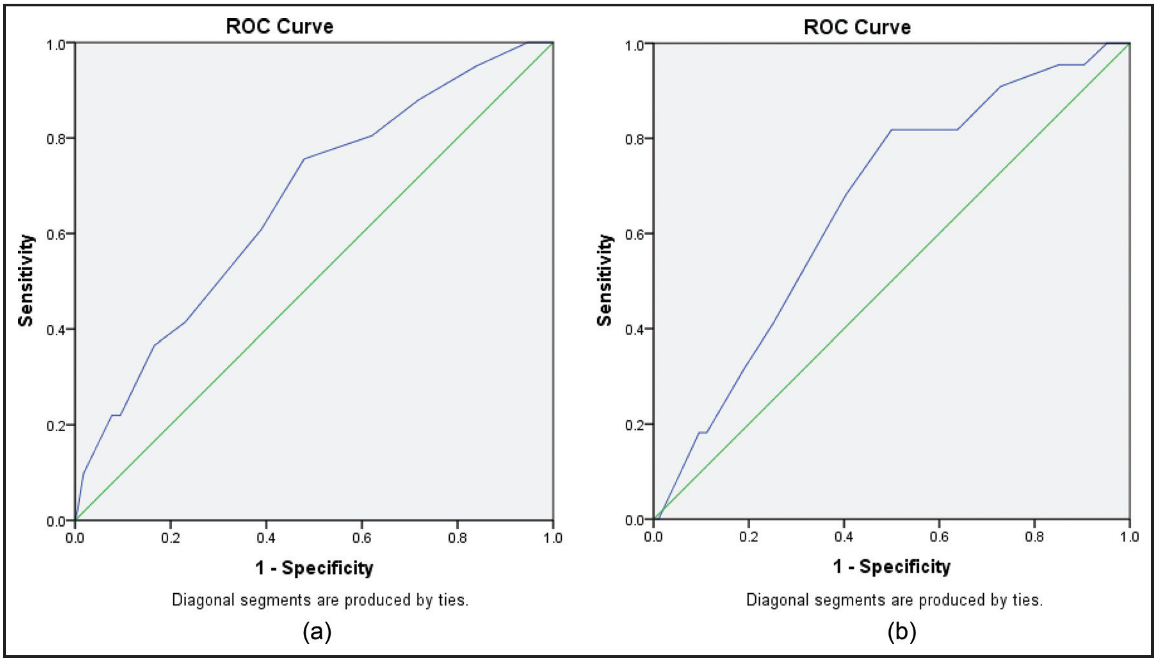

Figure 3. *(a) Receiver Operator Characteristic (ROC) Curve Associated with All Female Athletes (e.g., Combined Sample) and All LQ Injury during Sport. For this ROC curve: a "smaller" test result (e.g., younger age starting sport) was associated with a greater risk of injury. (b) Receiver Operator Characteristic (ROC) Curve Associated with All Female Athletes (e.g., Combined Sample) and Thigh or Knee Injury during Sport. For this ROC curve: a "smaller" test result (e.g., younger age starting sport) was associated with a greater risk of injury.*

RESULTS

Demographic information, off-season training habit reports, and LEFT scores for subjects in the validation sample and for the combined sample of D III athletes are presented in Table 1. Male athletes, in both samples, completed the LEFT significantly faster than their female counterparts ($p \leq 0.0001$). Male athletes also reported more time devoted to off-season training in each category except for plyometric training.

In this study, females in the validation study completed the LEFT in 113.1 (± 10.4) seconds and males completed the LEFT in 98.6 (± 8.1) seconds. Normative data for the LEFT has been previously reported based on either small sample sizes or for heterogeneous populations. Table 2 presents a comparison of LEFT scores between this study and prior studies.

Normative LEFT data per sport and gender is presented in Table 3 (this data includes LEFT scores for the combined sample). For all female D III athletes (n = 210) the mean LEFT score was 115.1 (± 10.6) seconds with a range of 91 to 162 seconds. For all male D III athletes (n = 185) the mean LEFT score was 101.6 (± 9.0) seconds with a range of 85 – 135 seconds. In each sex based comparison, males completed the LEFT significantly faster than their female counterparts.

A total of 34 non-contact time-loss LQ injuries were experienced by subjects in the validation sample (n = 206). Female athletes in the validation sample experienced 17 total non-contact time-loss LQ injuries with 12 occurring at the thigh or knee region and five occurring at the ankle or foot. Male athletes in the validation sample experienced 17 total non-contact time-loss LQ injuries with 14 occurring at the thigh or knee region and two occurring at the ankle or foot. For the combined sample (n = 395) a total of 78 non-contact time-loss LQ injuries were recorded. Female athletes sustained a total of 22 injuries to the thigh or knee, 17 injuries to the foot or ankle, and three injuries to other regions of the LQ. Male athletes sustained a total of 21 injuries to the thigh or knee, 11 to the foot or ankle, and 4 injuries to other regions of the LQ.

Odds ratios (OR) associated with the validation sample for female and male populations are presented in

Table 1. *Demographic Information and Lower Extremity Functional Test Scores (Seconds) for Female and Male Division III Athletes: Sex Based Comparisons for Validation Sample and for Combined Sample.*

Characteristic	Female Athletes [Validation Sample] (n = 104)	Male Athletes [Validation Sample] (n = 102)	p-value†	Female Athletes [Combined Sample] (n = 210)	Male Athletes [Combined Sample] (n = 185)	p-value†
Age (y)	19.2 (1.2)	19.5 (1.2)	0.1	19.2 (1.1)	19.5 (1.2)	0.01
Years in University (y)	2.2 (1.1)	2.0 (1.0)	0.2	2.1 (1.1)	2.1 (1.1)	0.7
Age Starting Sport (y)	11.1 (3.0)	10.3 (4.0)	0.08	11.1 (3.4)	10.3 (3.8)	0.03
Off-Season Training Habits (hr/wk)						
Weightlifting	3.4 (2.6)	4.0 (2.6)	0.1	3.2 (2.4)	4.4 (3.3)	≤ 0.0001
Cardiovascular Exercises	4.9 (2.7)	5.5 (3.9)	0.2	5.0 (3.2)	5.8 (4.0)	0.04
Plyometric Exercises	2.2 (2.0)	2.0 (1.8)	0.3	2.1 (2.0)	2.2 (2.2)	0.6
Scrimmage	1.9 (2.4)	3.0 (3.6)	0.02	2.7 (3.1)	3.8 (4.1)	0.002
Lower Extremity Functional Test (sec)	113.1 (10.4)	98.6 (8.1)	≤ 0.0001	115.1 (10.6)	101.6 (9.0)	≤ 0.0001

†Independent *t*-tests

Table 2. *Comparison of Lower Extremity Functional Test Scores (Seconds) between the Current Study (Validation Sample and Combined Sample) and Previously Reported Populations.*

Author(s) (Year)	Study Design	Population	LEFT Scores (sec)
Davies et al (2000)[1]	Clinical Commentary	Not presented	Females: 135 sec (ave.) (range: 120 – 150 sec) Males: 100 sec (ave.) (range: 90 – 125 sec)
Tabor et al (2002)[24]	Reliability	Population 1 N = 27 male Division III athletes; mean age 20.2 (range 18-24) years Population 2 N = 30 students (females = 18); mean age 22.9 (range 18-32) years	Population 1 Testing Session 1: 97.5 (±8.5) sec Testing Session 2: 97.2 (±9.1) sec Population 2 Testing Session 1: 111.6 (±10.6) sec Testing Session 2: 109.6 (±10.6) sec
Brumitt et al (2013)[4]	Prospective cohort	N = 189 Division III athletes (females = 106); mean age females 19.1 (± 1.1) years; mean age males 19.5 (± 1.3) years	Females: 117 (± 10) sec Males: 105 (± 9) sec
Current Study			
Validation Sample	Prospective cohort	N = 206 Division III athletes (females = 104); mean age females 19.2 (± 1.2) years; mean age males 19.5 (± 1.2) years	Females 113.1 (± 10.4) sec Males 98.6 (± 8.1) sec
Combined Sample	Prospective cohort	N = 395 Division III athletes (females = 210); mean age females 19.2 (± 1.1) years; mean age males 19.5 (± 1.2)	Females: 115.1 (± 10.6) sec Males: 101.6 (± 9.0) sec

Table 4. No significant relationships between LEFT measures and cutoff scores were found for either sex; thus unable to validate the risk profile previously reported[4] for a general D III athlete population.

Odds ratios for the combined sample were calculated and presented in Tables 5 and 6. Crude OR were calculated for demographics, off-season training habits, and LEFT scores by sex. Table 5 presents OR for

Table 3. *Comparison of Lower Extremity Functional Test Scores (Seconds) between Sexes based on Sport: Normative Data for 395 Division III Athletes.*

Sport	Female Athletes		Male Athletes		
	(N)	Mean (± SD)	(N)	Mean (SD)	*p*-value*
Basketball	(7)	117.4 (10.1)	(29)	101.6 (8.5)	≤ 0.0001
Soccer	(65)	113.7 (10.1)	(60)	99.4 (9.1)	≤ 0.0001
Cross-Country	(5)	113.8 (8.0)	(6)	101.7 (5.7)	0.02
Track & Field	(28)	115.4 (11.1)	(46)	100.6 (8.7)	≤ 0.0001
Tennis	(20)	119.8 (11.8)	(18)	103.8 (6.0)	≤ 0.0001
Softball (F) / Baseball (M)	(10)	115.8 (7.8)	(12)	105.0 (7.7)	0.004
Volleyball	(58)	116.3 (11.4)	NT		n/a
Wrestling	NT		(14)	108.5 (12.2)	n/a
Lacrosse	(17)	109.6 (6.9)	NT		n/a
Totals	(210)	115.1 (10.6)	(185)	101.6 (9.0)	≤ 0.0001
Range (sec)		91 – 162		85 – 135	

*Independent *t*-tests; F = female; M = male; NT = not tested, n/a = not assessed

Table 4. *Odds Ratios for Lower Extremity Functional Test Scores (Seconds) for Division III Athletes: Validation Sample.*

Characteristic	(N) at risk	All Injuries (%)	Odds Ratio (95% CI)	Thigh and Knee Injuries (%)	Odds Ratio (95% CI)	Foot and Ankle Injuries (%)	Odds Ratio (95% CI)
Females (n = 104)							
117 sec or less	74	(28)	1.0 (Referent)	(14)	1.0 (Referent)	(11)	1.0 (Referent)
118 sec or more	30	(23)	0.8 (0.3, 2.1)	(7)	0.5 (0.1, 2.2)	(13)	1.3 (0.4, 4.6)
120 sec or less	86	(27)	1.0 (Referent)	(12)	1.0 (Referent)	(11)	1.0 (Referent)
121 sec or more	18	(28)	1.1 (0.3, 3.3)	(11)	1.0 (0.2, 4.8)	(17)	1.7 (0.4, 7.1)
Males (n = 102)							
100 sec or less	65	(23)	1.0 (Referent)	(14)	1.0 (Referent)	(8)	1.0 (Referent)
101 sec or more	37	(24)	1.1 (0.4, 2.8)	(14)	1.0 (0.3, 3.2)	(5)	0.7 (0.1, 3.7)
105 sec or less	85	(26)	1.0 (Referent)	(15)	1.0 (Referent)	(7)	1.0 (Referent)
106 sec or more	17	(12)	0.4 (0.1, 2.0)	(6)	0.4 (0.0, 3.1)	(6)	0.9 (0.1, 7.9)

all (e.g., combined sample) female D III athletes. Only one category was associated with future risk of injury: age starting sport. Females who started participating in their primary sport at age 11 or older were significantly less likely (OR = 0.4, 95% CI: 0.2, 0.8; p = 0.01) to experience "any LQ injury" and less likely (OR = 0.3, 95% CI: 1.4, 10.0; p = 0.009) to experience a thigh or knee injury. Stated in the converse, female athletes who were 10 years of age or younger when starting sport were two times (OR = 2.4, 95% CI: 1.2, 4.9) more likely to experience any LQ injury and three times (OR = 3.2, 95% CI: 1.2, 8.1) more likely to experience a thigh or knee injury). Multivariate regression of demographic, training, or LEFT scores did not change risk profiles.

Table 6 presents OR for *all* (e.g., combined sample) male D III athletes. Only one category was

Table 5. *Crude Odds Ratios for Demographic and Lower Extremity Functional Test Scores for All (Combined Sample) Female Division III Athletes (N = 210).*

Characteristic	(N) at risk	All Injuries (%)	Odds Ratio (95% CI)	Thigh/Knee Injuries (%)	Odds Ratio (95% CI)	Ankle/Foot Injuries	Odds Ratio (95% CI)
Age (y)							
20 or above	70	(21)	1.0 (Referent)	(10)	1.0 (Referent)	(7)	1.0 (Referent)
19 or below	140	(19)	0.8 (0.4, 1.7)	(10)	1.0 (0.4, 2.6)	(7)	1.0 (0.3, 3.0)
Years in University (y)							
3 or more	72	(24)	1.0 (Referent)	(11)	1.0 (Referent)	(7)	1.0 (Referent)
2 or less	138	(17)	0.7 (0.3, 1.4)	(10)	0.8 (0.3, 2.1)	(6)	0.8 (0.3, 2.2)
Age Starting Sport (y)							
10 or younger	91	(28)	1.0 (Referent)	(17)	1.0 (Referent)	(9)	1.0 (Referent)
11 or older	119	(13)	0.4 (0.2, 0.8)†	(5)	0.3 (0.1, 0.7)‡	(6)	0.6 (0.2, 1.9)
Prior History of Injury							
Yes	147	(22)	1.6 (0.8, 3.7)	(12)	1.9 (0.6, 6.0)	(9)	3.0 (0.6, 13.5)
No	63	(14)	1.0 (Referent)	(6)	1.0 (Referent)	(3)	1.0 (Referent)
Weightlifting							
3 hr/wk or less	132	(18)	0.8 (0.4, 1.6)	(11)	1.2 (0.5, 3.1)	(5)	0.5 (0.2, 1.4)
>3 hr/wk	78	(21)	1.0 (Referent)	(9)	1.0 (Referent)	(10)	1.0 (Referent)
Cardiovascular exercise							
3 hr/wk or less	69	(13)	0.5 (0.2, 1.1)	(6)	0.4 (0.1, 1.4)	(4)	0.5 (0.1, 1.8)
>3 hr/wk	141	(23)	1.0 (Referent)	(12)	1.0 (Referent)	(9)	1.0 (Referent)
Plyometric exercise							
3 hr/wk or less	176	(19)	0.9 (0.4, 2.3)	(9)	0.6 (0.2, 1.7)	(7)	1.3 (0.3, 5.9)
>3 hr/wk	34	(20)	1.0 (Referent)	(15)	1.0 (Referent)	(6)	1.0 (Referent)
Scrimmaging							
3 hr/wk or less	144	(17)	0.7 (0.3, 1.3)	(10)	0.9 (0.3, 2.4)	(7)	0.9 (0.3, 2.8)
>3 hr/wk	66	(24)	1.0 (Referent)	(11)	1.0 (Referent)	(8)	1.0 (Referent)
Lower Extremity Functional Test							
Cut Score 1							
117 sec or less	133	(19)	1.0 (Referent)	(9)	1.0 (Referent)	(8)	1.0 (Referent)
118 sec or more	77	(21)	1.1 (0.6, 2.3)	(12)	1.4 (0.5, 3.3)	(5)	0.6 (0.2, 2.0)
Cut Score 2							
120 sec or less	156	(19)	1.0 (Referent)	(8)	1.0 (Referent)	(9)	1.0 (Referent)
121 sec or more	54	(22)	1.3 (0.6, 2.7)	(15)	1.9 (0.7, 4.9)	(2)	0.2 (0.0, 1.5)

†p-value = 0.01; ‡p-value = 0.009

associated with future risk of injury: off-season plyometric training. Males who reported performing plyometric exercises less than three hours a week were significantly less likely (OR = 0.3, 95% CI: 0.1, 0.9; p = 0.03) to experience a foot or ankle injury. In other words, males who reported performing greater than 3 hours per week of plyometric exercises were four times more likely (OR = 4.0, 95% CI: 1.1, 14.0) to experience a foot or ankle injury.

DISCUSSION

The primary purpose of this study was to validate or refute the previously reported[4] risk profile for athletes based on their preseason performance of the LEFT. The results of the current study were not able to validate the utility of the LEFT as an individual test to discriminate injury risk. A secondary purpose to this study was to evaluate demographic variables as potential risk factors. Only one demographic

Table 6. *Odds Ratios for Demographic and Lower Extremity Functional Test Scores for All (Combined Sample) Male Division III Athletes (N = 185).*

Characteristic	(N) at risk	All Injuries (%)	Odds Ratio (95% CI)	Thigh/Knee Injuries (%)	Odds Ratio (95% CI)	Ankle/Foot Injuries	Odds Ratio (95% CI)
Age (y)							
20 or above	84	(19)	1.0 (Referent)	(10)	1.0 (Referent)	(7)	1.0 (Referent)
19 or below	101	(20)	1.0 (0.5, 2.2)	(13)	1.4 (0.6, 3.6)	(5)	0.7 (0.2, 2.3)
Years in University (y)							
3 or more	54	(20)	1.0 (Referent)	(11)	1.0 (Referent)	(7)	1.0 (Referent)
2 or less	104	(21)	1.0 (0.5, 2.4)	(13)	1.1 (0.4, 3.2)	(6)	0.8 (0.2, 2.8)
Age Starting Sport (y)							
10 or younger	94	(23)	1.0 (Referent)	(14)	1.0 (Referent)	(6)	1.0 (Referent)
11 or older	91	(15)	0.6 (0.3, 1.3)	(7)	0.5 (0.2, 1.2)	(6)	0.9 (0.3, 2.9)
Prior History of Injury							
Yes	135	(20)	1.1 (0.5, 2.6)	(13)	1.7 (0.5, 5.2)	(5)	0.6 (0.2, 2.2)
No	50	(18)	1.0 (Referent)	(8)	1.0 (Referent)	(8)	1.0 (Referent)
Weightlifting							
3 hr/wk or less	79	(19)	0.9 (0.5, 2.0)	(14)	1.5 (0.6, 3.8)	(4)	0.5 (0.1, 1.9)
>3 hr/wk	105	(20)	1.0 (Referent)	(10)	1.0 (Referent)	(8)	1.0 (Referent)
Cardiovascular exercise							
3 hr/wk or less	58	(19)	1.0 (0.4, 2.1)	(12)	0.9 (0.3, 2.3)	(7)	1.3 (0.4, 4.5)
>3 hr/wk	127	(20)	1.0 (Referent)	(13)	1.0 (Referent)	(6)	1.0 (Referent)
Plyometric exercise							
3 hr/wk or less	150	(17)	2.3 (0.9, 5.3)	(11)	1.0 (0.3, 3.2)	(4)	0.3 (0.1, 0.9)‡
>3 hr/wk	35	(31)	1.0 (Referent)	(11)	1.0 (Referent)	(14)	1.0 (Referent)
Scrimmaging							
3 hr/wk or less	101	(19)	0.9 (0.4, 1.9)	(14)	1.4 (0.6, 3.6)	(5)	0.7 (0.2, 2.3)
>3 hr/wk	84	(20)	1.0 (Referent)	(12)	1.0 (Referent)	(7)	1.0 (Referent)
Lower Extremity Functional Test							
Cut Score 1							
100 sec or less	86	(22)	1.0 (Referent)	(13)	1.0 (Referent)	(7)	1.0 (Referent)
101 sec or more	99	(17)	0.7 (0.4, 1.5)	(10)	0.8 (0.3, 1.9)	(5)	0.7 (0.2, 2.4)
Cut Score 2							
105 sec or less	132	(22)	1.0 (Referent)	(19)	1.0 (Referent)	(6)	1.0 (Referent)
106 sec or more	53	(15)	0.7 (0.3, 1.6)	(13)	0.6 (0.2, 1.8)	(6)	0.9 (0.2, 3.6)

‡p-value = 0.03

variable (age starting sport ≤ 10 years) was associated with injury risk in female athletes and only one off-season training category (> 3 hr/week) was associated with injury risk in male athletes.

This study illustrates the importance of performing subsequent prospective cohort studies to assess preseason FPT measures and future injury risk in athletic populations. Based on the results in this study the LEFT should not be used in isolation to determine risk of injury in a general population of collegiate athletes.

The LEFT may have utility as a test for either a specific athlete population or as part of battery of tests for a general population of athletes. For example, a general population of D III female athletes that presented with suboptimal scores on a battery of FPT (shorter standing long jump measures, shorter single-leg hop for distance measures performed

bilaterally, and slower LEFT scores) were nine times more likely to experience a thigh or knee injury during sport.[28] Additional studies are warranted to identify the LEFT's predictive utility in either homogeneous sport populations or as one component of a battery of preseason performance tests.

In addition to assessing the utility of the LEFT as a predictor of injury, numerous demographic and off-season training variables were assessed for their ability to dichotomize athletes into at risk and lesser risk groups. For female athletes, the age starting sport was identified as a risk factor. Interestingly, female athletes who reported starting sport at a younger age (10 years of age or earlier) had a greater risk than those who started playing their primary sport at age 11 or older. A possible explanation for this finding may be related to sport specialization and the observation that athletes who participate in one sport experience a greater rate of injury when compared to those who participate in multiple sports.[29-33] Athletes who start sport participation at a later age may have been less likely to focus on only one sport throughout their adolescent athletic career. It is important to note though that information regarding the sport participation history for each athlete was not collected, thus this finding should be viewed with caution.

For male athletes time spent performing plyometric exercises during the six-week period prior to the official start of the preseason was associated with future foot and ankle injury. This finding is contrary to what one might expect. Plyometric training is considered an important component of athletic strength and conditioning training programs and injury prevention programs.[34,35] The authors do not suggest that an athlete or a team should reduce time devoted to plyometric training. Rather, it is possible that athletes that devoted more time in the off-season to unsupervised plyometric training devoted less total time to other forms of training that may have had a protective effect (e.g., injury protection). It should be noted that there is a lack of prospective studies assessing the role of training parameters (e.g., mode of exercise, volume, etc.) and subsequent risk of injury in a population of D III athletes.

A novel feature of this study is the presentation of sex and sport specific normative data for the LEFT. In this study's validation sample, male athletes completed the LEFT in 98.6 ($\pm$ 8.1) seconds and female athletes completed the LEFT in 113.1 ($\pm$ 10.4) seconds. Healthy female D III athletes, in this study and in prior studies,[4,24] appear to be able to complete the LEFT faster than originally described.[1] This may be due in part to the sample population from Davies et al[1] (athletic demographics unknown) or the sample's health status (e.g., recovering from injury vs. healthy status). Male D III athletes in this study appear to complete the LEFT in a period of time similar to those previously reported.[1,4,24] The LEFT is used clinically by rehabilitation professionals to assess an athlete's readiness to return to sport.[1-3] The presentation of normative data per sport and sex can aid clinicians as they make determinations regarding an athlete's ability to return to sport after a low back or LE injury.

Limitations

A few limitations to this study are noted. First, the risk profiles for females (age starting sport) and males (plyometric training) may be subject to recall bias. It is possible that an athlete under or over-reported training habits or the age that they started sport. Prospective cohort studies are warranted to confirm these findings. Second, the risk profiles presented here are for a general population of D III athletes and may not be generalizable to other levels of competition. Third, as part of this study athletic exposures (e.g., 1 AE = either participation in one practice or one game) were collected; however, this measure of exposure did not quantify exposure per minutes played (Note: collecting athletic exposures are necessary to calculate injury rates per LEFT cutoff scores. Injury rates based on cutoff scores were not calculated because there were no significant relationships between LEFT measures and sports injury occurrence). It is possible that categorizing athletes by their LEFT measures and exposures per minutes played during practice or competition could help discriminate at risk athletes.[36] For example, increased time playing in Division I football games was associated with injury.[36] However, increased playing time may not always be associated with greater injury risk. In a cohort of male, collegiate basketball players, one being a starter was no more likely to get injured than their non-starter counterparts.[25]

CONCLUSION

A prior study reported an association between preseason LEFT scores and subsequent injury in a general population of D III athletes. However, in this validation study, the LEFT test failed to discriminate athletes at risk for a sports injury. The LEFT may provide utility as a preseason performance test for either specific sport populations or as part of a battery of tests; however, this requires future study. Finally, the data presented in this study may aid rehabilitation professionals when evaluating an injured athlete's ability to return to sport by comparing their LEFT score to population norms.

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