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The Lower-Extremity Functional Test and Lower-Quadrant Injury in NCAA Division III Athletes: A Descriptive and Epidemiologic Report

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The Lower-Extremity Functional Test and Lower-Quadrant Injury in NCAA Division III Athletes: A Descriptive and Epidemiologic Report

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Context: The Lower-Extremity Functional Test (LEFT) has been used to assess readiness to return to sport after a lower-extremity injury. Current recommendations suggest that women should complete the LEFT in 135 s (average; range 120-150 s) and men should complete the test in 100 s (average; range 90-125 s). However, these estimates are based on limited data and may not be reflective of college athletes. Thus, additional assessment, including normative data, of the LEFT in sport populations is warranted. ***Objective:*** To examine LEFT times based on descriptive information and off-season training habits in NCAA Division III (Dill) athletes. In addition, this study prospectively examined the LEFT'S ability to discriminate sport-related injury occurrence. ***Design:*** Descriptive epidemiology. ***Setting:*** Dill university. ***Subjects:*** 189 Dill college athletes (106 women, 83 men) from 15 teams. ***Main Outcome Measures:*** LEFT times, preseason questionnaire, and time-loss injuries during the sport season. ***Results:*** Men completed the LEFT (105 ± 9 s) significantly faster than their female counterparts (117 ± 10 s) (***P*** **<** .0001). Female athletes who reported >3-5 h/wk of plyometric training during the off-season had significantly slower LEFT scores than those who performed <3 h/wk of plyometric training (***P*** **-** -03). The overall incidence of a lower-quadrant (LQ) time-loss injury for female athletes was 4.5/1000 athletic exposures (AEs) and 3.7/1000 AEs for male athletes. Female athletes with slower LEFT scores (>118 s) experienced a higher rate of LQ time-loss injuries than those with faster LEFT scores (<117 s) (***P*** **=** .03). ***Conclusion:*** Only off-season plyometric training practices seem to affect LEFT score times among female athletes. Women with slower LEFT scores are more likely to be injured than those with faster LEFT scores. Injury rates in men were not influenced by performance on the LEFT.

Keywords: agility, collegiate athlete, functional performance test, off-season

Athletes must possess some degree of agility (the ability to change direction and/or speed) to be competitive in sport.[1] In recent decades, sports-medicine professionals and strength coaches have used functional performance tests to assess agility in athletes. A functional performance test is an assessment tool that is reported to closely simulate a given sport or activity.[2,3] The ability of a test to mimic a functional movement or series of movements may provide information regarding an athlete's functional abilities and athletic readiness that may not be identified with traditional clinical assessment measures.[2-4] Several functional performance tests have assessed athletic agility and evaluated the effectiveness of training programs, including the figure-8 run, T-test, 505 Agility Test, and Illinois Agility Test.[5-12] Normative values for many of these tests have been reported for athletes based on gender, age ranges, and sport.[3]

The Lower-Extremity Functional Test (LEFT) is a functional performance test that has been used as a component of a return-to-sport rehabilitation testing algorithm.[13] The LEFT was initially designed to quantitatively and qualitatively assess the injured athlete's ability to perform sport-specific movement patterns.[13] The LEFT test involves 8 agility drills performed on a diamond-shaped course.[1334] In addition to assessing an athlete's ability to perform sport-specific movements, Davies and Zillmer[13] suggest that the test also evaluates cardiovascular fitness.[13] Average reported time for men to complete the LEFT is 100 seconds (range 90-125 s) and 135 seconds (range 120-150 s) for women.[13]

Despite its use in clinical rehabilitation, there are few reports available providing normative data or efficacy for the LEFT in assessing athletic readiness in different sport populations.[13-15] Thus, the 2 purposes of this study were to present normative data and relationships between LEFT scores with off-season training practices

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and injury incidence in a Division III (Dill) population. We hypothesized that male athletes would complete the LEFT significantly faster than their female counterparts. We also hypothesized that athletes who reported greater levels of off-season training would complete the LEFT significantly faster than those who reported less time training. A final purpose of this study was to prospectively examine the LEFT’Sability to discriminate sport-related injury occurrence. We hypothesized that athletes with slower LEFT times would have a significantly greater incidence of time-loss lower-quadrant (LQ) injury than athletes with faster LEFT times.

Methods

Participants

One hundred eighty-nine Dill college student-athletes (106 women, mean age 19.11± 1.10 y; 83 men, mean age 19.47 ± 1.27 y) from 15 university teams volunteered to participate in the study. Athletes were excluded from testing if they were currently unable to practice with the team due to injury or were under the age of 18. The institutional review boards of Rocky Mountain University of Health Professions and Pacific University approved this study.

Procedures

Study Questionnaire. Athletes completed a questionnaire including age, years enrolled at university, age starting their primary sport, and hours spent training per week during the 6 weeks before the start of the season (eg, sanctioned practice) in the following activities: weightlifting, cardiovascular exercise, plyometric exercise, and time spent scrimmaging.

LEFT Protocol. Each athlete completed a dynamic warm-up before performing the LEFT, consisting of 3 or 4 widths of forward walking, backward walking, heel walking, tip-toe walking, forward lunging, backward lunging, and high-knee marching (approximately 5 min). The warm-ups were performed between sidelines on a gymnasium court or across the width of a tennis court.

The LEFT course measures 9.14 m in a north-south direction and 3.05 m in a west-east direction (Figure 1). Equilateral triangles consisting of 0.305-m (1.0 ft) strips of athletic tape were placed at the ends of each axis.[13,14] The LEFT consists of 8 different agility tasks, with each task being performed twice.[3,13,14]

Each athlete started the test positioned behind the “A” triangle. Because of the multidirectional requirements of the test and variety of tasks performed during the LEFT, subjects were told that they would run in a forward direction from cone A to cone C and back.[3,14] Verbal instruction of subsequent movements was provided throughout the test. As a subject neared completion of the first task (as well as with each subsequent task) an investigator would provide verbal instructions describing the task and the direction of movement.[14] Each athlete performed 1 trial of the LEFT.

Injury Surveillance. The university’s athletic training staff maintained participation (eg, athletic-exposure [AE]) and -injury records for all athletes. The operational definition for an AE was participation in practice or a game where the athlete was at risk for an injury.[16,17] Only time-loss LQ (LQ = low back and lower extremities) injuries were recorded for analysis.

Records of AEs and time-loss-injury data were reviewed weekly by a study investigator to ensure that data were being collected in a timely fashion, as well as to ensure record completeness. An initial injury was the first time-loss LQ injury experienced during the season.[16-18] A subsequent injury was any additional LQ time-loss injury experienced during the remainder of the season.[16-18] Injury severity was categorized as minor (time loss from sport <8 d) or moderate/major (time loss from sport >8 d).[18]

1. Forward sprint (A-C-A)
2. Retro sprint (A-C-A)
3. Side shuffle right - face in (A-D-C-B-A)
4. Side shuffle left - face in (A-B-C-D-A)
5. Cariocas right - face in (A-D-C-B-A)
6. Cariocas left - face in (A-B-C-D-A)
7. Figure 8s right (A-D-C-B-A)
8. Figure 8s left (A-B-C-D-A)
9. 45° Cuts right - plant outside foot (A-D-C-B-A)
10. 45° Cuts left - plant outside foot (A-B-C-D-A)
11. 90° Cuts right - plant outisde foot (A-D-B-A)
12. 90° Cuts left - plant outside foot (A-B-D-A)
13. Crossover 90° cuts right - plant inside foot (A-D-B-A)
14. Crossover 90° cuts left - plant inside foot (A-B-D-A)
15. Forward sprint (A-C-A)
16. Retro sprint (A-C-A)

10 ft

Figure 1 — The Lower-Extremity Functional Test.

Statistical Analysis

Descriptive statistics (mean ± SD) were calculated for baseline demographic characteristics and LEFT scores. The t-test was used to compare LEFT scores between sexes. Off-season training habits were categorized using the following groups: 0 to 1, >1 to 3, >3 to 5, and >5 h/wk. LEFT scores were compared across these groups for men and women separately using an analysis of variance (ANOVA). A post hoc Bonferroni correction was performed to identify significance between subcategories within a group.

Injury rates were calculated per 1000 AEs for initial and subsequent injuries, then by injury-severity classification. Rates were assessed for women and men separately using a cut score based on mean LEFT scores (faster mean score or less; slower score or more) by specific sex for this study's sample.[16,17] Separate sex-specific rate ratios (RRs) and 95% confidence intervals (CIs) were calculated to compare injury rates between athletes with faster and slower LEFT scores based on injury onset and severity. A survival-curve analysis was performed using the Kaplan Meier statistic. Data analysis was performed using OpenEpi (for incidence rates and RRs) and SPSS Statistics 17 (Chicago, IL) with the alpha level set at .05.

Results

Table 1 presents mean (± SD) LEFT scores per demographic characteristics and off-season training habits. Men had significantly faster LEFT scores (105 ± 9 s) than their female counterparts (117 ± 10 s) ($P < .0001$). There were no significant within-group differences for male athletes in LEFT scores by age group, age starting primary sport, years enrolled in college, or prior history of a time-loss sports injury. Female athletes who reported performing >3 to 5 h/wk of plyometric exercises had significantly slower LEFT scores (128 ± 21 s) than those who reported >1 to 3 h/wk (116 ± 8 s; $P = .02$) or 0 to 1 h/wk (116 ± 9 s; $P = .03$) of plyometric training. There were no other significant within-group differences for female athletes in LEFT scores and the other off-season training practices.

The overall injury incidence rate for female athletes was 4.5/1000 AEs (95% Cl = 3.1, 6.2) (Table 2). The incidence of an initial time-loss LQ injury was 3.8/1000 AEs (95% Cl = 2.5, 5.5) and 10.4/1000 AEs (95% Cl = 4.8, 19.7) for those who experienced a subsequent injury. Most injuries (72%, n = 23) were of minor severity (3.2/1000 AEs, 95% Cl = 2.1,4.7). Female athletes with slower (>118 s) LEFT scores were twice as likely (RR = 2.2, 95% Cl = 1.1, 4.4, $P = .03$) to incur 1 or more (total) time-loss injuries than those with faster (<117 s) LEFT scores. Female athletes with slower LEFT scores were as likely to have at least an initial injury as those with faster LEFT scores; however, the risk was not statistically significant (RR = 1.6, 95% Cl = 0.7, 3.6, $P = .26$). Women with slower LEFT scores were 6 times more likely to incur 1 or more subsequent injuries than those with faster LEFT scores (RR = 6.4, 95% Cl = 1.0, 146.0, $P = .05$). Women with slower LEFT scores were also 6 times more likely to incur a minor LQ time-loss injury (RR = 6.2, 95% Cl = 2.1, 18.1, P S .0001) than those with faster LEFT scores. Conversely, women with faster LEFT scores were more likely to incur a moderate/major LQ time-loss injury than those with slower LEFT scores (RR = 0.2, 95% Cl = 0.0, 1.0, P = .05).

The overall injury incidence rate for male athletes was 3.7/1000 AEs (95% Cl = 2.4, 5.4) (Table 3). The incidence of an initial time-loss LQ injury was 3.2/1000 AEs (95% Cl = 2.0, 5.0) with those experiencing subsequent injuries at 8.5/1000 AEs (95% Cl = 3.1, 18.8). While male athletes with faster (<105 s) LEFT scores were more likely to incur 1 or more (total) time-loss injuries (RR = 0.7, 95% Cl = 0.3, 1.6, $P = .4$) than those with slower (>106 s) LEFT scores, the protective effect was not statistically significant. The risks for initial, subsequent, or severity between faster and slower male athletes were also not statistically significant ($P > .05$).

A Kaplan-Meier survival-curve analysis illustrates timing of LQ time-loss injuries in female (Figure 2) and male (Figure 3) athletes relative to AEs. Women with faster LEFT scores (mean AEs to injury = 25, 95% Cl = 14.5, 35.5) were more apt to experience an LQ injury earlier in the season than those with slower LEFT scores (mean AEs to injury = 31.4, 95% CI= 3.2, 25.1). Forty-five percent (5/11) of female athletes with faster LEFT scores had experienced a time-loss injury within the first 20 AEs. Conversely, only 1 of 13 female athletes with slower LEFT scores had experienced a time-loss injury by the twentieth AE.

Men with slower LEFT scores (mean AEs to injury = 24.5,95% Cl = 6.7, 11.3) were more likely to experience an initial LQ injury earlier in the season than those with faster LEFT scores (mean AEs to injury = 42.1,95% Cl = 6.4,29.6). Fifty percent (3/6) had experienced a time-loss injury within the first 20 AEs. Only 2 of 13 (15%) male athletes with faster LEFT scores experienced a time-loss injury by the twentieth AE.

Discussion

To our knowledge, this is the first study to present normative data for the LEFT in a healthy, general Dill college athletic population. Male athletes were significantly faster at completing the LEFT than the female athletes. Only 1 significant relationship existed between reported off-season training habits and mean LEFT scores (slower female athletes reported greater time performing plyometrics). Women with slower LEFT scores experienced a significantly higher rate of time-loss LQ injuries than their faster counterparts.

Table 1 Mean (± SD) Scores (s) on the Lower-Extremity Functional Test for Division III Athletes

	Women			Men		
Scores by characteristic	**n**	**Mean ± SD**	**P**	**n**	**Mean ± SD**	**P**
Totals	106	117 ± 10		83	105 ±9	<.0001*
Demographic Characteristics						
Age (y)			.99			.13
18	38	117 ± 11		24	107 ±11	
19	34	118 ± 13		21	102 ±6	
20	21	117 ± 7		20	107 + 7	
21 and older	13	116 ± 5		18	106 ±9	
Age starting sport (y)			.33			.30
<12	69	118 ± 10		54	106 ±9	
13-15	25	116 ± 12		26	106 ±9	
>16	12	113 ±9		3	98 + 6	
Years in university			.89			.12
1	41	117 ± 14		29	106 ± 10	
2	30	118 ± 9		22	102 ±8	
3	25	116 ± 8		20	109 ±8	
4 or more	10	118 ± 5		12	104 ±7	
Previous history of sports injury			.65			.20
yes	73	117 ± 11		55	106 ± 10	
no	33	116+10		28	104 + 6	
Preseason Training (h/wk)						
Weightlifting			.61			.14
0-1	29	119 + 8		10	104 ±4	
>1-3	37	116 ± 9		23	108 ±11	
>3-5	27	118 ± 15		23	106 + 9	
>5	13	115 ± 8		27	103 ±7	
Cardiovascular exercise			.71			.84
0-1	6	116 ± 8		10	105 ±12	
>1-3	29	116 + 9		15	106 + 8	
>3-5	34	117 ± 10		13	103 ±5	
>5	37	119 ± 12		45	106 ±9	
Plyometric exercise			.03			.71
0-1	45	116 ± 9f		38	106 ± 10	
>1-3	47	116 ± 8$		23	105 ±7	
>3-5	8	128 ± 21ti		11	107 ±5	
>5	6	116 ± 10		11	103 ±10	
Scrimmage			.51			.13
0-1	38	116 ± 9		24	108 ± 10	
>1-3	24	116 ± 8		14	106 ±5	
>3-5	22	120 ± 13		13	107 ±9	
>5	22	118 ± 12		32	103 ±9	

independent f-test for comparing scores between women and. men; all other /'-values based on ANOVA. tDifferences between 0-1 and >3-5; P-value .03 post hoc, Bonferroni correction test. ^Differences between >1-3 and >3-5; P-value .02 post hoc, Bonferroni correction test

Table 2 Injury Rates per 1000 AEs and Injury Severity, Female Division III College Athletes

	Total			LEFT 118 s or More			LEFT 117 s or Less			
Injury category	**n**	**AEs**	**Rate**	**n**	**AEs**	**Rate**	**n**	**AEs**	**Rate**	**Rate ratio[a] (95% CI)**
Onset										
initial	24	6400	3.8	13	2718	4.8	11	3682	3.0	1.6 (0.7, 3.6)
subsequent	8	771	10.4	7	402	17.4	1	369	2.7	6.4 (1.0,146.0)
total	32	7171	4.5	20	3120	6.4	12	4051	3.0	2.2 (1.1, 4.4)
Severity										
<8 d time loss	23	7171	3.2	19	3120	6.1	4	4051	1.0	6.2 (2.1, 18.1)
>8 d time loss	9	7171	1.3	1	3120	0.3	8	4051	2.0	0.2 (0.0, 1.0)

Abbreviations: AE, athletic exposure; LEFT, Lower-Extremity Functional Test.
[a] LEFT 118 or more vs LEFT 117 or less.

Table 3 Injury Rates per 1000 AEs and Injury Severity, Male Division III College Athletes

	Total			LEFT 118 s or More			LEFT 117 s or Less			
Injury category	**n**	**AEs**	**Rate**	**n**	**AEs**	**Rate**	**n**	**AEs**	**Rate**	**Rate ratio[a] (95% CI)**
Onset										
initial	19	5873	3.2	6	2262	2.6	13	3611	3.6	0.7 (0.3, 1.9)
subsequent	5	589	8.5	1	224	4.5	4	365	10.9	0.4 (0.0, 3.6)
total	24	6462	3.7	7	2486	2.8	17	3976	4.3	0.7 (0.3, 1.6)
Severity										
<8 d time loss	15	6462	2.3	5	2486	2.0	10	3976	2.5	0.8 (0.3, 2.4)
>8 d time loss	9	6462	1.4	2	2486	0.8	7	3976	1.8	0.5 (0.1, 2.2)

Abbreviations: AE, athletic exposure; LEFT, Lower-Extremity Functional Test.
[a] LEFT 106 or more vs LEFT 105 or less.

The LEFT has been historically described in the literature as a test to assess aspects of athletic readiness before returning an athlete to sport after a traumatic knee injury.[13] Current recommendations suggest that women should complete the LEFT in 135 seconds (average; range 120-150 s) and men should finish the test in 100 seconds (average; range 90-125 s).[13] However, these prior clinical recommendations are based on few reports and small sample sizes, which may limit their generalizability to other college-athlete populations. Tabor et al[14] published scores for 2 sets of healthy, college-age subjects. The first subject group consisted of 27 men (mean age 20.2 y, range 18–24) from a DIII student-athlete population. This group's times for 2 trials were 97.52 ± 8.53 and 97.18 ± 9.05 seconds. These times were faster than the DIII male athletes' LEFT times in our study (105 ± 9 s). The difference in scores may be due to sample-size differences and type of athletes. This study sampled a general heterogeneous athletic population, whereas the sport backgrounds of the athletes from Tabor et al[14] were not reported. The second group consisted of 30 subjects (12 male, 18 female; mean age 22.9 y, range 18-32) from a nonathlete student population. The mean times for this group's 2 trials were 111.61 ± 10.62 and 109.61 ± 10.63 s. The second group's slower mean times may be a result of the group being older, consisting of non-student-athletes, and including women. To our knowledge there are no other reports of normative data available for a female college athletic population. The female athletes in that study completed the LEFT in 117 ± 10 seconds, which was faster than prior reported clinical recommendations. Of interest for rehabilitation professionals is that 68% (72 out of 106) of the DIII female athletes in our study completed the LEFT faster than the prior clinical recommendation score of 120 seconds (fastest score in the range of 120-150 s). These data suggest that the average LEFT score (and range) for female athletes may need reexamining, at least when applied to DIII college athletes.

LEFT scores were also analyzed per demographic data and off-season training habits. Only 1 category, off-season plyometric training habits in female athletes, had a significant within-group difference. Women who

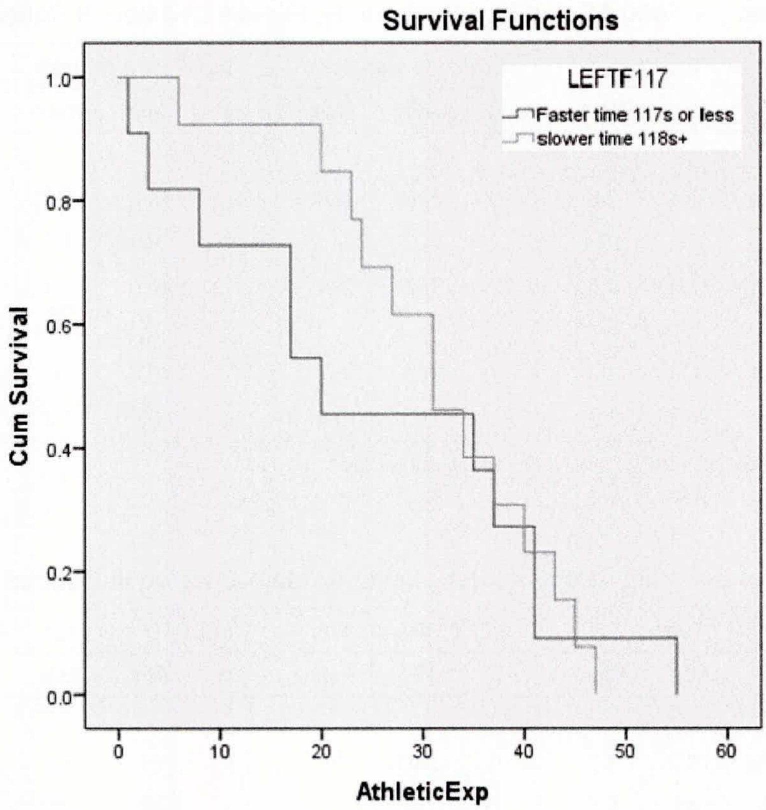

Figure 2 — Kaplan-Meier survival curve, female Division III athletes. Abbreviations: Cum, cumulative; Exp, exposure.

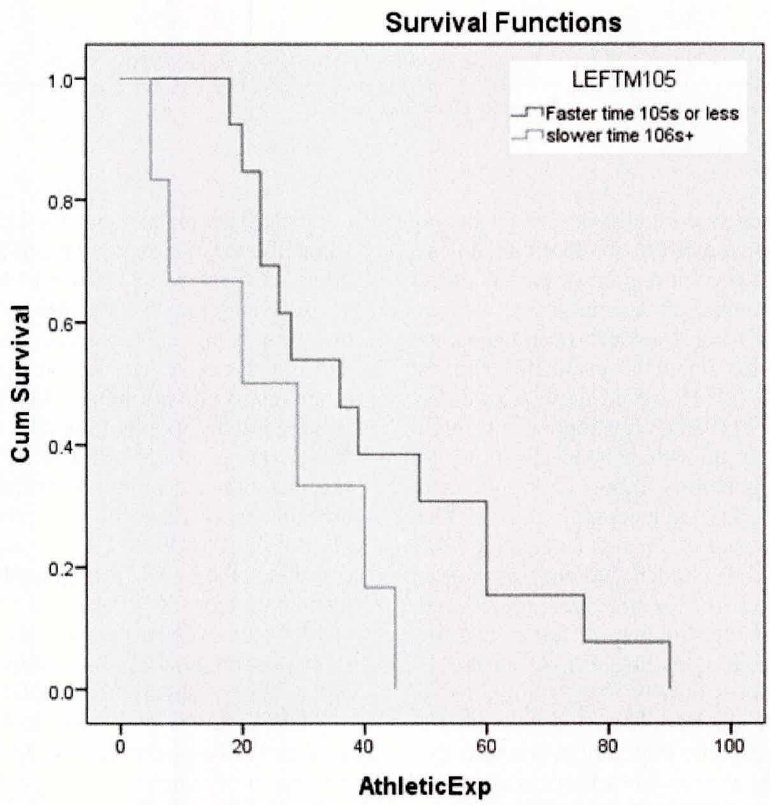

Figure 3 — Kaplan-Meier survival curve, male Division III athletes. Abbreviations: Cum, cumulative; Exp, exposure.

reported performing >3-5 h/wk of plyometric exercises were significantly slower than those who devoted less time per week to plyometric exercises. It is possible that athletes who devoted more time to plyometric exercises either spent less time training to enhance speed and agility or performed sports not requiring these attributes (eg, throwing sports). More studies are warranted to identify normative scores per sport.

Researchers have reported associations between time-loss sport injuries and functional-performance-test measures in athletic populations.[15,19-22] The prospective design of this study and the collection of AEs and time-loss injuries allowed for the assessment of initial and subsequent injury incidence rates and RRs. We hypothesized that athletes with slower LEFT scores would have a higher incidence of time-loss LQ inquires. This hypothesis was supported among the female athletes, as those with slower LEFT scores (>118 s) experienced a greater number of time-loss LQ injuries. This finding may be the result of insufficient conditioning before starting the sport season. Female athletes with slower LEFT scores also experienced a greater number of minor LQ injuries. Although female athletes with faster LEFT scores were less likely to experience an LQ time-loss injury during the season, when injured, they were more apt to incur their injury earlier in the season. Forty-five percent of these athletes had experienced an LQ time-loss injury within the first 20 AEs. Conversely, only 1 of 13 athletes with a slow LEFT score had experienced a LQ time-loss injury by the twentieth AE. We speculate that these athletes may have received more total playing time in practices and games and thus may be at an increased risk for injury earlier in the season. However, this remains an area for future research.

The strengths associated with this study included its prospective design and its overall sample size. To our knowledge, this study presents the largest LEFT data set for healthy male and female athletes. Weekly communication with university-certified athletic trainers on a prospective basis ensured accurate data collection of AEs and time-loss injuries.

Another strength of the study is the use of an inexpensive, easy-to-perform test. At the Dill college level (as well as at the high school level or other small-college settings) coaches and sports-medicine professionals have limited time to physically prepare athletes before competition. The use of a test such as the LEFT can provide coaches and sports-medicine professionals with measures of athletic readiness. Athletes who are in optimal fitness at the start of the season may have a lower risk of a time-loss injury during the season. Optimal fitness, or readiness, for sport may be multifactorial. Researchers are attempting to identify factors such as motor control, asymmetries, balance, and strength before the start of a sports season that may be associated with risk of injury.[19-24] Athletes who have been identified in the preseason as having asymmetries in range of motion or deficits in strength, balance, motor control, and speed can receive targeted training programs by the coaching staff to address deficiencies.

Some limitations of our study should be noted. First, despite the large sample size, this data may have limited generalizability to other college athletic populations. In addition, there may be differences in mean LEFT scores based on sport type (eg, soccer players may have a different profile than softball players). However, the sample sizes in individual sports precluded us from determining significant difference. Second, we calculated AEs based on daily participation (eg, either participation in practice or game). This measure of AE is less precise than collecting measures of participation based on total minutes of exposure. Third, while some injury rates for the at-risk group were much higher than injury rates for the group considered at less risk, the findings were not statistically significant, most likely due to a small number of injuries for each group. Fourth, while it can be argued that there may be different pathomechanics between contact and noncontact injuries, we included all time-loss injuries in our study analyses for several reasons. Many studies that have used functional tests to assess injury risk have included contact and noncontact injuries.[20-22] Kiesel et al[20] reported an 11-fold increased risk of a time-loss injury of 3 weeks duration or longer in professional football players who scored 14 or less on the Functional Movement Screen. In other words, professional football players who presented with fewer movement asymmetries and better motor control, as measured by the Functional Movement Screen, had a protective effect. Plisky et al[22] included traumatic injuries when calculating risk association between time-loss injuries in high school basketball players and their preseason performance on the Star Excursion Balance Test. They included diagnoses such as ankle sprains or knee sprains in their definition of traumatic injuries. These types of injuries (eg, ankle or knee sprain) can be the result of contact or noncontact mechanisms. It is important to appreciate that in most team sports there is a chance of encountering physical play. It is also important to appreciate that most athletes who experience the forces associated with physical play do not sustain a time-loss injury. Finally, at the Dill level (as well as in other situations where an athletic trainer is unable to be available at all moments), an athletic trainer may have to rely on the athlete or coach to provide the method or causal mechanism of injury.

Conclusion

Slower LEFT scores were associated with a greater incidence of injury for Dill female college athletes. The descriptive and epidemiologic data may be useful for sports-medicine professionals when assessing an athlete's potential readiness to return to sport after LQ injury, as well as an athlete's risk for LQ injury.

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