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Risk Factors Associated with Noncontact Time-Loss Lower-Quadrant Injury in Male Collegiate Soccer Players

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ABSTRACT

Introduction: The incidence of time-loss injury in male collegiate soccer players in the United States (US) is 6.4 per 1000 athletic exposures. With thousands of male athletes competing in soccer at the US collegiate level each year, there is the potential for numerous time-loss injuries that may ultimately impact team success. Thus, identifying risk factors for injury is warranted.

Purpose: The primary purpose of this study was to determine if preseason functional performance test (FPT) measures (the standing long jump [SLJ] and single-leg hop [SLH] for distance tests) were associated with an increased risk of a noncontact time-loss lower-quadrant (LQ) injury during the season. The secondary purpose of this study was to explore relationships between off-season training volumes and to determine if off-season training habits are associated with time-loss LQ injury.

Results: Preseason FPT measures were not associated with an increased risk of time-loss LQ injury in male collegiate soccer players. However, lower levels of off-season training were associated with a threefold increased risk of injury.

Conclusion: The SLJ and SLH may not be useful at discriminating risk of injury in male collegiate soccer players. Lower volume of time devoted to training in the off-season is associated with an increased risk of LQ injury.

Practical implications: The SLJ and SLH tests should not be used as a screening tool to assess for risk of injury in male collegiate soccer players. The total volume of exercise performed during the week in the off-season is associated with future risk of LQ injury. The preliminary data presented here could be used by coaches to assist with their design of off-season strength training programs. Finally, the normative SLJ and SLH data presented can be used by sports medicine professionals when functionally assessing LE strength and one's ability to return to sport after injury.

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KEYWORDS
Epidemiology; functional test; soccer (football); standing long jump; single-leg hop

Introduction

Soccer (known as football throughout the world) is an extremely popular sport played across the globe by athletes of all ages, genders, and skill levels. Injuries to the lower quadrant (LQ: low back and lower extremities) are common in soccer with athletes risking injury via both contact and noncontact mechanisms. The most common injuries in male soccer players include sprain and strain injuries to the ankle, knee, and thigh regions and contusions to the leg, ankle, and foot regions (Powell & Dompier 2004).

Injury rates have been reported for male collegiate soccer players who compete in the United States (Powell & Dompier 2004). The overall injury rate (a rate that includes both non–time-loss and time-loss injuries) for all levels of collegiate competition is 31.0 per 1000 athletic exposures (AEs) (range 23.5–39.9 per 1000 AEs) (Powell & Dompier 2004). (Note: an AE is any official team practice or competition). The overall non–time-loss injury rate is 24.5 per 1000 AEs (range 16.4–34.7 per 1000 AEs) and the overall time-loss injury rate is 6.4 per 1000 AEs (5.4–8.5 per 1000 AEs) (Powell & Dompier 2004). Thousands of male soccer players compete in the United States (US) at the collegiate level each year; thus, there is the potential for numerous sports-related injuries during the season. All injuries are of concern for coaches and sports medicine professionals; however, time-loss injuries may significantly impact a team's success.

Identifying athletes at risk for injury either during the off-season or early preseason may allow coaches and/or sports medicine professionals to intervene with injury prevention training programs. A recent trend in sports medicine research has been to assess the ability of functional performance tests (FPTs) to discriminate sport-related injury occurrence. FPT is a test that simulates a functional movement or series of movements; thus, screening athletes with FPTs may identify aspects of athletic readiness (e.g., strength, flexibility, etc.) that may not be appreciated with traditional clinical tests (e.g., manual muscle testing, goniometry, etc.) (Cook, Burton, & Hoogenboom; 2006a, 2006b; Reiman & Manske 2009; Manske & Reiman 2013). The Y balance test (YBT), the Functional Movement Screen™ (FMS), the standing long jump (SLJ), the single-leg hop (SLH) for distance, and the Nordbord have been assessed for their ability to discriminate injury risk in soccer players (Brumitt et al. 2013; Opar et al. 2015; Smith et al. 2015; Timmins et al. 2016; Warren et al. 2015; Mokha et al. 2016).

The aforementioned research represents FPTs that have been prospectively evaluated in soccer players (in most

cases, a general population of athletes that consisted of collegiate soccer players). The equivocal findings associated with many of these studies, as well as the heterogeneous subject populations and differences in the operational definitions for what constitutes an injury (e.g., inclusion of non–time-loss versus only time-loss injuries), may leave coaches and sports medicine professionals with uncertainty as to which test, or series of tests, can best discriminate overall injury risk in male collegiate soccer players.

The primary purpose of this study was to determine if individual SLJ and SLH preseason measures and/or a combination of FPT scores were associated with an increased risk of a noncontact time-loss LQ injury during the season. It was hypothesized that soccer players with shorter SLJ and/or SLH distances would be at greater risk for injury. A secondary purpose of this study was twofold: (1) to examine relationships between off-season training volumes and preseason FPT measures and (2) to determine associations between training habits and noncontact time-loss LQ injury. It was hypothesized that athletes who reported more time training during the off-season would jump and hop significantly farther and would have a lower risk of injury than their counterparts.

Methods

Participants

A total of 77 male collegiate soccer players (mean age 19.6 years ± 1.3; mean height 1.79 m ± 0.08; and mean weight 75.4 kg ± 8.2) from 4 collegiate soccer teams (competition levels: from one NCAA Division I team, two NCAA Division III teams, and one NAIA team) volunteered to participate in the study. A participant was included in this study if they were able to participate in sport without restriction from the team physician and/or certified athletic trainer. A participant was excluded from study participation if he was under the age of 18 years. Informed consent was obtained from athletes prior to testing. The Institutional Review Board of George Fox University (Newberg, OR, USA) approved this study.

Testing protocol

Collection of demographic information and FPT measures occurred at the start of each team's preseason. First, each athlete completed a questionnaire that collected the following information: age, years at university, age starting sport, and the average time spent training each week during the 6-week period prior to the start of the official preseason (i.e., sanctioned practice) for each of the following categories: weightlifting, cardiovascular exercise, plyometric exercise, and scrimmaging. Second, height (cloth tape) and weight (standard medical scale) measures were collected. Third, each athlete performed a 5-min dynamic warm-up consisting of the following activities: forward lunging, backward lunging, walking on heels, walking on toes, and high knee marching. Finally, each athlete performed 6 SLJ (3 submaximal and 3 maximal effort jumps) and 6 SLH (3 maximal effort hops per lower extremity [LE]). FPT measures were collected by the primary investigator (PI).

Standing long jump

An athlete stood with feet positioned shoulder width apart behind a piece of tape placed on the floor. A cloth tape for measuring distance jumped/hopped was positioned perpendicular to the starting line. Each athlete performed 3 submaximal effort SLJs followed by 3 maximal effort SLJs. Athletes were required to clasp their hands behind their back during each jump (Davies & Zillmer 2000). For a jump to be measured, the athlete would have to stick and hold the landing for 5 s. A SLJ trial was repeated if the athlete failed to stick the landing. The mean of the 3 jumps was used for data analyses. The PI's test–retest reliability ($ICC_{3,3}$) for the SLJ (0.96 [95% confidence interval {CI}: 0.83–0.97]) has been previously reported (Brumitt et al. 2014).

SLH for distance

The SLH test was performed after the athlete successfully completed 3 SLJ. Each athlete performed 6 SLH; 3 for each LE. A coin toss determined which leg the athlete hopped off of first. For an SLH trial to be measured, the athlete had to keep his hands clasped behind the back and stick the landing for 5 s (Davies & Zillmer 2000). An SLH trial was repeated if the athlete unsuccessfully performed the hop. The mean of 3 hops per LE was used for data analyses. The PI's test–retest reliability ($ICC_{3,3}$) for the SLH ([R] SLH 0.95 [95% CI: 0.89–0.98]; [L] SLH 0.96 [95% CI: 0.89–0.98]) has been previously reported (Brumitt et al. 2014).

Injury surveillance

Injury records were collected daily, over the course of the Fall collegiate season (approximately 4 months), by each university's athletic training staff. The athletic trainers collected the following characteristics for each injured athlete: body region, type of injury (e.g., strain, sprain, fracture, etc.), and the total time lost from sport participation. The operational definition of an injury was any muscle, joint, or bone problem/injury of the low back or the LE (categorized by the following regions: low back, hip, thigh, knee, leg, ankle, or foot) that occurred during practice or competition via a noncontact mechanism that required the athlete to be removed from that day's event or to miss a subsequent practice or competition (Rauh et al. 2006; Brumitt et al. 2013). The primary investigator reviewed injury records weekly to check the accuracy of data collection.

Statistical analysis

An a priori sample size estimation of 67 participants was calculated based on annual LQ injury reports from the university's athletic training staffs (Brumitt et al. 2013). A total of 77 male collegiate soccer players were recruited from 4 different teams.

Descriptive statistics (means ± standard deviation [SD]) were calculated for the soccer players' baseline demographics, anthropometric measures, off-season training habits, and FPT measures. Mean FPT scores were normalized as a percentage of body height. Comparisons between injured and uninjured athletes were calculated by performing independent *t*-tests. Anthropometric measures (e.g., height, weight, and body mass index [BMI]) were categorized as (−1 SD [shortest, lightest, or lowest]/mean [average]/+1 SD [tallest, heaviest, or highest]). Off-season training habits were categorized into the following

groups: 0–3/>3–5/>5 h per week (Brumitt et al. 2014, 2016). Mean FPT scores were calculated per anthropometric measures and off-season training habits. Analysis of variance (ANOVA) was performed to assess for differences in FPT measures within each group. A *post hoc* Bonferroni test was performed after ANOVA to identify the significant differences between subcategories within a group.

A receiver-operator characteristic (ROC) curve was performed for each FPT and for off-season training levels to identify cutoff scores. The ROC curves failed to identify a point that maximized sensitivity and specificity per FPT; thus, previously reported cutoff scores were used to dichotomize soccer players into "at risk" and "referent" (e.g., lesser risk) groups (Davies & Zillmer 2000; Brumitt et al. 2013). The cutoff scores for the SLJ were 89% of one's height or less [at risk]/≥90% [referent]. The cutoff score for the SLH test was 79% of one's height or less [at risk]/≥80% [referent]. The cutoff score for the limb symmetry index (LSI; percentage difference between SLH measures) was >10% [at risk]/10% or less [referent]. ROC curves also failed to identify points that maximized sensitivity and specificity for off-season training volumes per individual category. Athletes were dichotomized into either at-risk groups (0–3 h per week) or referent groups (3+ hours per week) per each training category (Brumitt et al. 2014). Total training volume (e.g., total hours spent training per week) was analyzed as a potential risk factor with athletes dichotomized into at risk groups (less overall training) and referent groups (more overall training). Univariate logistic regression was performed to calculated odds ratios (ORs) and 95% CIs. Data analysis was performed using OpenEpi (injury rates) and SPSS Statistics 22 (Chicago, IL, USA) with the alpha level set a 0.05.

Results

Mean (±SD) jump/hop measures for this sample were 0.98 (±0.12) for the SLJ; 0.84 (±0.12) for the (R) SLH; and 0.85 (±0.12) for the (L) SLH (Table 1). There were no significant differences in demographic characteristics, off-season training habits, or FPT measures between soccer players who experienced a time-loss LQ injury during the season and their uninjured counterparts (Table 1).

A total of 27 initial noncontact time-loss injuries occurred for a rate of 5.5 per 1000 AEs (95% CI: 3.7–7.8). The diagnoses associated with the 27 initial injuries were 1 lumbar strain, 1 hip flexor strain, 2 groin strains, 3 quadriceps strains, 4 hamstring strains, 4 knee sprains, 1 case of shin splints, 1 gastrocnemius strain, 9 lateral ankle sprains, and 1 great toe sprain. A total of 10 subsequent noncontact time-loss injuries were experienced in this population (subsequent injury was any injury experienced by a soccer player after his initial injury) for a rate of 11.2 per 1000 AEs (95% CI: 5.7–20.0). The following diagnoses were associated with the 10 subsequent injuries: 1 groin strain, 1 quadriceps strain, 4 knee sprains, and 4 lateral ankle sprains.

Table 2 presents ORs associated with injury risk based on individual preseason FPT measures, LSI (= difference in hop distance between LEs), and multiple preseason FPT measures. Risk associations were categorized into the following regions: all LQ injuries, injuries to the thigh/knee region, and injuries to the foot/ankle region. There were no significant differences in risk between at risk and referent groups for each FPT category (individual FPTs, multiple FPTs, and LSI categories).

Table 3 presents normalized FPT measures categorized by athlete age and anthropometric measures. There were no differences in SLJ and SLH measures based on age category. There were significant differences in jump and hop measures based on height. Soccer players in the shorter (−1 SD) and average (mean) height categories jumped significantly farther than taller (+1 SD) players ($P = 0.001$; *post hoc* $P = 0.002$ and $P = 0.001$, respectively). Soccer players in the shorter- and average-height categories also hopped significantly farther than their taller counterparts. Shorter- and average-height athletes hopped with the (R) LE significantly farther than taller athletes ($P = 0.001$; *post hoc* $P = 0.004$ and $P = 0.002$, respectively). Similarly, shorter- and average-height athletes hopped significantly farther with the (L) LE than their taller counterparts ($P = 0.005$; *post hoc* $P = 0.009$ and $P = 0.009$, respectively). There was a *trend* toward significance for FPT measures based on weight with soccer players in the lighter- and average-weight categories jumping/hopping farther than heavier counterparts. There were no significant relationships between BMI and FPT measures.

Table 4 presents mean (±SD) FPT measures based on off-season training variables. Off-season training habits were

Table 1. Demographic characteristics and normalized functional performance test measures (mean ± standard deviation) of male collegiate soccer players.

Characteristic	All soccer players (n = 77)	Athletes not injured during the season (n = 50)	Athletes injured during the season (n = 27)	P-value[ab]
Age (years)	19.6 ± 1.3	19.6 ± 1.4	19.7 ± 1.1	0.5
Years in university/college	2.3 ± 1.1	2.2 ± 1.1	2.5 ± 1.2	0.2
Age starting sport (years)	8.2 ± 3.1	8.3 ± 3.0	7.9 ± 3.1	0.6
Height (m)	1.79 ± 0.08	1.79 ± 0.09	1.80 ± 0.07	0.8
Weight (kg)	75.4 ± 8.2	74.7 ± 8.5	76.8 ± 7.8	0.3
Body mass index ($kg \cdot m^2$)	23.4 ± 1.6	23.3 ± 1.7	23.7 ± 1.5	0.2
Off-season training (h/week)				
Weightlifting	4.9 ± 4.5	4.9 ± 3.5	4.7 ± 6.0	0.9
Cardiovascular exercise	8.5 ± 4.3	8.2 ± 4.6	9.0 ± 3.6	0.4
Plyometric exercise	3.2 ± 2.7	3.2 ± 2.8	3.2 ± 2.7	0.9
Scrimmage	5.3 ± 4.0	5.5 ± 4.4	5.0 ± 3.2	0.6
Functional performance test measures				
Standing long jump	0.98 ± 0.12	0.99 ± 0.12	0.97 ± 0.12	0.5
(R) Single-leg hop	0.84 ± 0.12	0.84 ± 0.12	0.84 ± 0.11	0.9
(L) Single-leg hop	0.85 ± 0.12	0.84 ± 0.12	0.85 ± 0.11	0.8

[a]Independent *t*-tests.
[b]Comparison of means between soccer players injured or not injured during the season.

Table 2. Odds ratios for noncontact lower-quadrant musculoskeletal injury based on functional performance test scores for male collegiate basketball players.

	N at risk	All injuries (%)	Odds ratio	95% CI	Thigh/knee injuries (%)	Odds ratio	95% CI	Ankle/foot injuries (%)	Odds ratio	95% CI
N = 77 SLJ as a percent of one's height										
90% or more	58	(31)	1.0	Referent	(14)	1.0	Referent	(14)	1.0	Referent
89% or less	19	(47)	2.0	(0.7–5.8)	(21)	1.7	(0.4–6.3)	(26)	2.2	(0.6–7.9)
(R) SLH as a percent of one's height										
80% or more	55	(36)	1.0	Referent	(16)	1.0	Referent	(16)	1.0	Referent
79% or less	22	(32)	0.8	(0.3–2.3)	(14)	0.8	(0.2–3.3)	(18)	1.1	(0.3–4.2)
(L) SLH as a percent of one' height										
80% or more	52	(37)	1.0	Referent	(17)	1.0	Referent	(15)	1.0	Referent
79% or less	25	(32)	0.8	(0.3–2.2)	(12)	0.7	(0.2–2.7)	(20)	1.4	(0.4–4.7)
Limb symmetry index (LSI)										
10% or less	24	(46)	1.0	Referent	(21)	1.0	Referent	(21)	1.0	Referent
More than 10%	53	(30)	0.5	(0.2–1.4)	(13)	0.6	(0.2–2.1)	(15)	0.7	(0.2–2.3)
Each FPT score below CR										
Yes (All 3)	13	(39)	1.2	(0.4–4.1)	(15)	0.9	(0.2–5.1)	(23)	1.6	(0.4–6.9)
No (2 or less)	64	(34)	1.0	Referent	(16)	1.0	Referent	(16)	1.0	Referent
Each FPT score below CR and LSI >10%										
Yes (all 4 below)	9	(33)	0.9	(0.2–4.0)	(11)	0.6	(0.1–5.7)	(22)	1.5	(0.3–8.1)
No (3 or less)	68	(35)	1.0	Referent	(16)	1.0	Referent	(16)	1.0	Referent

FPT: functional performance test (e.g., SLJ and SLH); CR: clinical recommendation; CI: confidence interval; SLJ: standing long jump: LSI: limb symmetry index .

Table 3. Normalized functional performance test measures (mean ± standard deviation [SD]) by age and anthropometric measures for male collegiate soccer players.

	Standing long jump		Single-leg hop (R)		Single-leg hop (L)	
Variable	*N* (mean ± SD)	*P*-value[a]	*N* (mean ± SD)	*P*-value[a]	*N* (mean ± SD)	*P*-value[a]
Age (years)						
18	20 (1.01 ± 0.11)	0.3	20 (0.85 ± 0.13)	0.5	20 (0.86 ± 0.14)	0.5
19	15 (1.01 ± 0.09)		15 (0.87 ± 0.10)		15 (0.87 ± 0.08)	
20	25 (0.96 ± 0.12)		20 (0.83 ± 0.13)		25 (0.84 ± 0.13)	
21 and older	17 (0.96 ± 0.13)		17 (0.82 ± 0.09)		17 (0.82 ± 0.10)	
Totals	77 (0.98 ± 0.12)		77 (0.84 ± 0.12)		77 (0.85 ± 0.12)	
Height (m)						
Shortest (−1 SD)	12 (1.03 ± 0.11)[b]	0.001	12 (0.88 ± 0.10)[d]	0.001	12 (0.89 ± 0.11)[f]	0.005
Average	53 (1.00 ± 0.11)[c]		53 (0.86 ± 0.11)[e]		53 (0.86 ± 0.12)[f]	
Tallest (+1 SD)	12 (0.88 ± 0.10)[bc]		12 (0.73 ± 0.10)[de]		12 (0.75 ± 0.09)[f]	
Weight (kg)						
Lightest (−1 SD)	11 (0.98 ± 0.10)	0.06	11 (0.86 ± 0.08)	0.054	11 (0.87 ± 0.08)	0.05
Average	53 (0.99 ± 0.11)		53 (0.85 ± 0.11)		53 (0.86 ± 0.12)	
Heaviest (+1 SD)	13 (0.91 ± 0.14)		13 (0.77 ± 0.13)		13 (0.77 ± 0.12)	
Body mass index						
Lowest (−1 SD)	16 (0.98 ± 0.08)	0.8	16 (0.85 ± 0.06)	0.8	16 (0.85 ± 0.08)	0.8
Average	49 (0.98 ± 0.12)		49 (0.84 ± 0.12)		49 (0.85 ± 0.13)	
Highest (+1 SD)	12 (1.00 ± 0.14)		12 (0.82 ± 0.14)		12 (0.82 ± 0.14)	

[a]ANOVA: analysis of variance.
[b]Difference between shortest and tallest heights; *P*-value = 0.002 *post hoc*.
[c]Difference between average and tallest heights; *P*-value = 0.001 *post hoc*.
[d]Difference between shortest and tallest heights; *P*-value = 0.004 *post hoc*.
[e]Difference between average and tallest heights; *P*-value = 0.002 *post hoc*.
[f]Difference between shortest/tallest and average/tallest heights; *P*-value = 0.009 *post hoc*.

categorized into three groups: 0–3 h per week, >3–5 h per week, and >5 h per week. Only off-season plyometric training habits were associated with differences in SLH measures. Those who reported 0–3 h per week of plyometric exercises hopped significantly farther ([R] SLH $P = 0.05$; [L] SLH $P = 0.02$) than those who reported >3 h per week of plyometric training.

Table 5 presents OR associated with reported off-season training habits. Individual training categories were dichotomized into the following groups: 0–3 h per week (at risk) />3 h per week (referent or lesser risk). There was no greater risk of injury based on reported off-season individual training categories; however, assessing cumulative training reports revealed a greater risk of LQ injury. Two cumulative training categories were analyzed: (1) athletes who reported 0–3 h of training per week in 2 or more categories (at risk group; $n = 37$; mean total training time 15.4 [4.6] h per week) and the referent group ($n = 40$; mean total training time per week = 27.8 [9.5] h per week) and (2) athletes who reported 0–3 h in training per week in 3 or more categories (at risk group = 18; mean total training time 14.6 [5.6] h per week) and the referent group ($n = 59$; mean total training time 24.1 [9.7] h per week). Athletes who reported only performing 3 h or less per week in 3 or more of the 4 assessed categories were 3 times more likely to experience a noncontact time-loss injury than their counterparts (OR = 3.1; 95% CI: 1.0–9.2; $P = 0.04$).

Discussion

Preseason performance of the SLJ, SLH, or a combination of these tests was not associated with an increased risk of LQ injury in male collegiate soccer players. Of interest to coaches

Table 4. Normalized functional performance test measures (mean ± standard deviation [SD]) by off-season training habits for male collegiate soccer players.

Off-season training variables (h/week)	Standing long jump N (mean ± SD)	P-value*	Single-leg hop (R) N (mean ± SD)	P-value*	Single-leg hop (L) N (mean ± SD)	P-value
Totals	77 (0.98 ± 0.12)		77 (0.84 ± 0.12)		77 (0.85 ± 0.12)	
Weightlifting						
0–3	35 (0.97 ± 0.12)	0.4	35 (0.84 ± 0.10)	0.4	35 (0.86 ± 0.11)	0.5
>3–5	16 (0.96 ± 0.11)		16 (0.81 ± 0.12)		16 (0.81 ± 0.11)	
>5	26 (1.00 ± 0.11)		26 (0.86 ± 0.13)		26 (0.85 ± 0.14)	
Cardiovascular exercise						
0–3	6 (1.00 ± 0.08)	0.7	6 (0.84 ± 0.10)	0.9	6 (0.86 ± 0.08)	0.7
>3–5	71 (0.98 ± 0.12)		71 (0.84 ± 0.12)		71 (0.84 ± 0.12)	
>5	0 –		0 –		0 –	
Plyometric exercises						
0–3	49 (1.00 ± 0.11)	0.07	49 (0.86 ± 0.11)	**0.05**	49 (0.87 ± 0.12)	**0.02**
>3–5	28 (0.95 ± 0.13)		28 (0.81 ± 0.11)		28 (0.80 ± 0.11)	
>5	0 –		0 –		0 –	
Scrimmaging						
0–3	28 (0.98 ± 0.12)	0.7	28 (0.83 ± 0.12)	0.6	28 (0.84 ± 0.12)	
>3–5	49 (0.99 ± 0.12)		49 (0.85 ± 0.12)		49 (0.85 ± 0.12)	
>5	0 –		0 –		0 –	

Table 5. Off-season training habits as risk factors for time-loss lower-quadrant musculoskeletal injury in male collegiate soccer players ($N = 77$).

	N at risk	All injuries (%)	Odds ratio	95% CI	Thigh/knee injuries (%)	Odds ratio	95% CI	Ankle/foot injuries	Odds ratio	95% CI
Categories Weightlifting										
0–3 h/week	35	(43)	1.9	(0.7–4.8)	(20)	1.9	(0.5–6.5)	(17)	1.0	(0.3–3.4)
>3 h/week	42	(29)	1.0	Referent	(12)	1.0	Referent	(17)	1.0	Referent
Cardiovascular exercise										
0–3 h/week	6	(17)	0.4	(0.0–3.1)	(0)	[a]	[a]	(0)	[a]	[a]
>3 h/week	71	(37)	1.0	Referent	(17)	1.0	Referent	(18)	1.0	Referent
Plyometric exercise										
0–3 h/week	49	(39)	1.5	(0.5–4.3)	(18)	1.9	(0.5–7.6)	(16)	0.9	(0.3–3.1)
>3 h/week	28	(29)	1.0	Referent	(11)	1.0	Referent	(18)	1.0	Referent
Scrimmaging										
0–3 h/week	28	(43)	1.7	(0.6–4.5)	(21)	2.0	(0.6–6.8)	(14)	0.7	(0.2–2.7)
>3 h/week	49	(31)	1.0	Referent	(12)	1.0	Referent	(18)	1.0	Referent
Training categories combined[b]										
2 or more categories (15.4 [4.6] h/week)	37	(38)	1.3	(0.5–3.3)	(16)	1.1	(0.3–3.8)	(16)	0.9	(0.3–3.0)
1 or less categories (27.8 [9.5] h/week)	40	(33)	1.0	Referent	(15)	1.0	Referent	(18)	1.0	Referent
3 or more categories (14.6 [5.6] h/week)	18	(56)	**3.1**	**(1.0–9.2)**[c]	(27)	2.9	(0.8–10.5)	(17)	1.0	(0.2–4.0)
2 or less categories (24.1 [9.7] h/week)	59	(29)	1.0	Referent	(11)	1.0	Referent	(17)	1.0	Referent

[a]No injuries in at risk group.
[b]Cut score 0–3 h per week within each training category.
[c]$P = 0.04$.
CI: confidence interval.

and sports medicine professionals was the finding that athletes who reported lower levels of overall off-season training habits had a threefold increased risk of LQ injury.

The primary purpose of this study was to assess the SLJ and SLH FPTs as tools to screen soccer players for future risk of injury. To our knowledge, this is the first study to assess these FPTs in male collegiate soccer players. It appears that these tests may not be useful for identifying athletes who may be at a greater risk of LQ injury during the season. Other FPTs, such as the YBT and the FMS, have been reported to identify collegiate athletes at risk for future injury (Smith et al. 2015; Warren et al. 2015; Mokha et al. 2016). However, these tests have only been applied to heterogeneous populations, and thus, the reported cut scores from those studies should be applied to male collegiate soccer players with caution. Assessment of hamstring strength with the Nordbord has been prospectively performed with a homogeneous population of elite male soccer players and thus appears to be a useful test for identifying soccer players at risk for a hamstring injury (Timmins et al. 2016). A limitation associated with this test is that it appears to *only* screen athletes for hamstring strains. Due to the equivocal findings and/or narrow injury focus (e.g., hamstring injury only) associated with the aforementioned studies, additional prospective cohort studies are warranted to assess the utility of other FPT measures as preseason screening tools in male collegiate soccer teams.

The FPT descriptive data reported in this study may be clinically useful to sports medicine professionals when rehabilitating soccer players after an LQ injury. The SLJ and SLH tests are frequently utilized to assess the progress during rehabilitation and to guide discharge planning (Davies & Zillmer 2000). Davies et al. (2000) recommends that athletes should be able to jump at least 90% of their height and hop at least 80% of their height. Based on the data presented in this study, it may be appropriate to require male collegiate soccer players to jump and hop farther

than the minimum recommended distances prior to returning an athlete back to sport.

The secondary purpose of this study was to assess FPT measures and injury risk based on off-season training habits. The primary collegiate soccer season in the US starts in the late summer when students return to campus after the summer break. Typically, coaches provide their athletes with off-season training programs; it is the responsibility of the athlete to complete their training independently. Appreciating off-season training habits is of interest to coaches and sports medicine professionals because potential relationships between training habits and injury risk may influence off-season program design. Off-season training habits were collected from a questionnaire completed by each athlete. In this study, athletes reported their off-season training habits with the understanding that their coaches would not have access to their individual reports, thus increasing the likelihood that the soccer players correctly reported their training volumes. Only off-season plyometric training habits were associated with differences in FPT measures. Interestingly, those who reported more time performing plyometric training (>3 h per week) had significantly shorter hop measures than those who reported 0–3 h of plyometric training per week. This finding is counter to what might be expected and thus this finding should be viewed with caution. Recall bias is possible explanation for this finding. Future investigations should assess functional measures of strength and power (e.g., SLJ and SLH) based on supervised training programs.

Off-season training volumes were associated with an increased risk of LQ injury during the soccer season. Analysis of individual training categories was not associated with increased risk; however, training volume across multiple categories was associated with a threefold increased risk of LQ injury. While it could be assumed that athletes who spend more time training during the off-season would be more resilient (e.g., injury resistant), this is the first study to our knowledge to report this finding. This finding is clinically useful to strength coaches and may help guide the design of off-season training programs.

The strengths associated with this study include its prospective design, the homogenous population (e.g., male collegiate soccer players), the operational definition of an injury (e.g., time-loss and noncontact mechanism), and the utilization of inexpensive, easy-to-use FPTs. A potential limitation associated with this study is the reliance on the athletes' off-season training reports. First, the relationship between reported off-season training and FPT scores does not suggest a cause-and-effect relationship. Second, we only collected information regarding average time devoted to each training category; there was no analysis on program design. A prospective study utilizing a supervised training program would be necessary to determine a cause-and-effect relationship between off-season training and preseason performance. Third, even though there was an association between lower volumes of total training time across categories and an increased risk of LQ injury, we are unable to define a protective (e.g., injury prevention) training volume for this population. Future prospective studies are warranted to determine an optimal off-season training program.

Conclusion

The SLJ and SLH FPTs do not appear to be useful as a tool to assess the injury risk in male collegiate soccer players. Total training volume (e.g., lower levels of overall off-season training habits) was associated with an increased risk of injury.

Disclosure statement

No potential conflict of interest was reported by the authors.

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