VALIDITY OF FUNCTIONAL SCREENING TESTS TO PREDICT LOST-TIME LOWER QUARTER INJURY IN A COHORT OF FEMALE COLLEGIATE ATHLETES

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ABSTRACT

Background: Lower quarter injuries account for more than 50% of all injuries in collegiate athletics. Neuromuscular screening tests could potentially identify athletes who are at risk for sustaining an injury. While previous research has studied individual tests, the authors of this paper are unaware of any study that has compared diagnostic accuracy of multiple neuromuscular screening tests within one study cohort.

Hypothesis/Purpose: The purpose of this study was to examine the accuracy of three common neuromuscular screening tests to predict the occurrence of a lower quarter injury in female collegiate volleyball and basketball players.

Study Design: Prospective Cohort

Methods: Thirty-five subjects underwent a pre-season screening by performing the Y-balance test, the Functional Movement Screen™, and Single Leg Hop test. Data were collected on lower quarter injury incidence, lost practice time, and lost competition time among subjects throughout the course of one season. Receiver operating characteristics curves were plotted and area under the curve was calculated to assess the relationship between lower extremity injury incidence and the scores of the functional tests.

Results: Lost-time injuries occurred in 11 athletes (31.4%), of whom, six athletes (17.1%) lost 50 hours or greater. There were no significant relationships between occurrence of a lost-time lower extremity injury and scores on any of the three tests. Positive and negative likelihood ratios all included the value of 1.0.

Conclusions: Although reliable, the screening tests under study did not appear to retain adequate validity to predict lower quarter injury risk within these female collegiate athletes.

Level of Evidence: Level 2b

Key words: Ankle, hip, injury prediction, knee, lower quarter, lumbar, movement system, relative risk, sports

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INTRODUCTION

Lower extremity injuries present a considerable burden to athletes' team performance and lost playing time, with potential economic effects on the conference, University, and intercollegiate athletics as a whole. Data from the National Collegiate Athletic Association (NCAA) Injury Surveillance System indicate women's basketball athletes to have an injury rate of 6.54 injuries per 1,000 exposures, with 59% of these injuries occurring in the lower extremity.¹ Women's collegiate volleyball injury incidence has been reported at 40.6 injuries per 1,000 exposures, with 65.5% occurring in the lower extremity.² Additionally, descriptive epidemiological data shows that both women's collegiate volleyball and basketball players are at higher risk of injury in the pre-season compared to regular and postseason.^{3,4} Based on the analysis of risk factors in these epidemiological studies, it is clear that athletic injuries are always 'unintentional' but not always 'accidental,' and that at least some risks may be modified or mitigated.

Given the prevalence and severity of lower extremity injuries in intercollegiate athletics, there may be special interest in assessing injury risk profiles in athletes in order to create individualized plans to manage modifiable risks. The prerequisite for validity is reliability; screening tests must be highly reliable in order to be valid to predict lower quarter injuries. Three common screening tools demonstrate good interrater reliability, including the Y-balance test (YBT) (ICC 0.85-0.93 + /- 2.0-3.5 cm)⁵ the Functional Movement Screen™ (FMS™) (ICC 0.843),⁶ and the Single Leg Hop (SLH) test (ICC 0.97 + /- 5.0-5.3 cm).⁷ The Y-balance test involves standing on one leg and reaching three directions with the non-stance leg. Of the three measured directions, a left to right difference of >4 cm with the anterior reach has demonstrated 59% sensitivity and 72% specificity values for injury occurrence in a prospective study design.⁸ The FMS™ ranks seven fundamental movement patterns, incorporates three clearing tests, and is designed to screen for major movement limitations and asymmetries to determine potential injury risk.⁹ Recently, Garrison et al studied the FMS™ predictive ability of injury in 160 collegiate men's and women's athletes and found a positive likelihood ratio of 5.8 for a FMS™ composite score of 14 or less being predictive of injury during sport.¹⁰ A component of the

YBT and FMS™ that may be potentially missing is the assessment of higher-impact dynamic aspects of sports, often performed in basketball and volleyball, such as landing from a jump.¹¹⁻¹³ A third screening test, the Single Leg Hop (SLH) test, assesses a single limb hop jump distance on one leg compared to the other. A study completed on 193 Division III athletes showed that a difference of >10% between sides on the SLH test correlated to a four fold increase in ankle or foot injury occurrence.¹⁴

Despite a growing body of evidence suggesting these screening tools may be predictive of lower quarter injury, there are various gaps in the existing literature. Studies have investigated single screening tools but have not yet studied several screening tools within one study. Also, studies have found these tests are valid screening tools in large cohorts,^{8,10-12,14,15} but there is a lack of investigation into the ability of the YBT, FMS™, and SLH tests to predict injury occurrence within single team cohorts. This is important since one purpose of these tests is to use them as part of a screening process to predict lower quarter injury risk in individual team cohorts, smaller than the typical sample sizes analyzed in research articles. Thus, the purpose of this study was to examine the accuracy of the YBT, FMS™, and SLH tests to predict the occurrence of a lower quarter injury in female collegiate volleyball and basketball players. The authors of this study hypothesized that the results of one or more of these screening tools studied would accurately predict lower quarter injury occurrence in this population.

METHODS

Subjects

The study was approved by the institutional review board prior to beginning the pre-testing. Inclusion criteria utilized were 1) subjects had to be a member of Hillsdale College's women's basketball or women's volleyball team and 2) they had to have currently been practicing and participating in competition without injury. The rationale for these criteria are that the authors sought to examine injury prediction in a smaller cohort, thus other sports and other genders were excluded. It was also important that subjects were uninjured as the study aimed to follow healthy athletes and their risk for developing

injury. All subjects provided informed consent prior to participation in the study.

Pre-testing Procedure

Prior to beginning the study, all tests were performed by a physical therapist on six random test subjects, outside the target subject pool. These six subjects were tested following the same protocol later described in the methods section for the YBT, FMS™ and SLH. The same tester was used for this pre-testing procedure in order to gain experience and refine study method protocols. The results were analyzed to determine intra-rater reliability of the tester performing the screening tests.

Screening Tests Procedures

An investigator who is a physical therapist performed the formal screening tests. This investigator had three years of experience using each of these tests in the clinical setting and was certified in the FMS™ prior to start of this study. Protocol for this study required subjects to first receive an explanation and demonstration of each screening test. For all included subjects, the same investigator (author 1) provided the explanations and demonstrations of each test. Each of the three screening tests and methods are listed below.

The Y-Balance Test: Testing protocol for the YBT was similar to previous testing on the Star Excursion Balance Test.¹² Subjects took position with their toes at the center of a grid that had measuring tape marked off in three different directions- anterior, posteromedial, and posterolateral (Figure 1). The subjects performed each direction with six practice trials and then three measured trials with the best score for each direction being used. These scores were normalized to limb length for statistical analysis. Subjects performed anterior, posteromedial, and posterolateral reach with the right foot prior to reaching each direction with the left foot. Scores were not used if subjects were unable to return their reach leg back to the center of the grid while maintaining single leg balance on the contralateral side.

Functional Movement Screen™ (FMS™): Subjects performed each segment using FMS™ certified equipment (Figure 2). The study investigator assessing the subjects was an FMS™ certified examiner.

Figure 1. Y-Balance test performed using tape grid.

Figure 2. Performance of the Overhead Deep Squat screen, one part of the Functional Movement Screen™.

Component tests of the FMS™ were rated by a standardized examiner on a 3-point scale. Pain during the movement was scored as 0. A composite score for the FMS™ was calculated by summing the item scores.

Figure 3. Performance of the Single Leg hop test.

Single Leg Hop (SLH): Each subject stood barefoot with her toes on a designated starting marker and jumped for distance off of one foot while landing on the same foot and maintaining single leg balance after landing (Figure 3). Single leg balance was to be maintained for at least one second, with this time being estimated by the investigator. Each subject went through six practice trials on each limb and then had three test attempts for their furthest distance. Distance was measured by marking where the posterior edge of the heel landed and the longest distance for each limb was recorded.

Data Collection

Observational data collection began following completion of the pre-testing procedure. Data were collected and recorded for thirty-five subjects on a standard data collection form. This form included weekly sport practice hours, strength and conditioning hours, injuries sustained during activity, and hours missed due to injury. A weekly observational

subject data sheet was filled out after consulting coaching staff and athletic training staff for official counts of each variable. Weekly observations were made for 33 weeks. Data forms were assessed for predictive ability of pre-screening tests to injury incidence. Lower quarter injury incidence was defined as an injury to the low back, hip, knee, ankle, or foot regions, during participation in athletic team activities that resulted in a minimum of one lost day of practice or the inability to participate in at least one full competition.

Statistical Methods

Sample Size Considerations: A Receiver Operating Characteristic (ROC) curve is a graphical representation of the trade-off between the false negative and false positive rates for every possible cut off of a diagnostic test. The accuracy of a diagnostic test (i.e. the ability of the test to correctly classify those athletes that may get injured vs. those who do not) is measured by the area under the ROC curve. An area of 1.0 represents a perfect diagnostic test, while an area of 0.50 represents an inaccurate test or essentially one that is comparable to flipping a coin. Statistically, more area under the curve means that the test is identifying more true positives while minimizing the number/percent of false positives. Although there is limited published data to determine power for this study's sample size, the authors of this study found results from Plisky et al, 2006 to be adequate to base a current power analysis from.¹² Assuming an injury rate of 25% (based on Table 5 in Plisky et al., 2006) a sample of seven injured athletes and 28 non-injured will provide 80% power to detect a difference of 0.324 between the area under the ROC curve (AUC) under the null hypothesis of 0.50 and an AUC under the alternative hypothesis using a two-sided z-test at a significance level of 0.05. If injury rate in this study is $\geq 25\%$, this study would have adequate power to detect a difference. The above calculations apply to each of the three diagnostic tests separately. In addition, the authors also tested for differences in AUC between the three diagnostic tests with alpha adjusted for inflation to 0.0167.

Statistical/Power Analysis Plan: Intra-rater reliability analysis was conducted in order to confirm high intrarater reliability for all preseason screening tests (FMS™ subscale score, FMS™ total score, SLH, and

YBT). Intraclass correlation coefficient (formula 2,1) and Cohen's Kappa were used to assess intrarater reliability for continuous and categorical variables, respectively. Incidence of lost-time injury was the basic unit of analysis for this study. Differences in demographics between injured and non-injured players were analyzed with Student's t-test and chi-square tests for continuous and categorical variables, respectively. Continuous variables were represented as mean $\pm$ SD or median (range) and categorical variables were reported as a percentage. All hop distances and YBT reach distances were standardized to the athlete's limb length. Receiver operating characteristics (ROC) curve analysis and area under the curve (AUC) calculation was used to determine the association between screening test result and incidence of lost-time injury. Alpha was set at 0.05 and all analyses were conducted with SAS v. 9.3 (SAS Institute Inc., Cary, NC) and/or SPSS v. 21, (IBM Corp).

RESULTS

Pre-testing results

Intrarater reliability measures from the pre-testing procedure revealed that Cohen's K values ranged from .700 $\pm$.241 to 1.00 for the FMS™ composite and its individual components. P-values for all functional tests included values from $< .001$ to .165 (Table 1). All reliability measures reflect adequate reliability except for YBT Posteromedial Left measurement, which had a measure of .435 $\pm$.000-.992. The authors are unsure as to why the posteromedial left measurement was not reliable. It can be surmised that a motor learning effect may have accounted for the variability that was observed in this particular measurement for the six random subjects used for pilot testing. Perhaps the reliability could have been studied further if more test subjects were used for the pre-testing procedure. At any rate, the detailed protocol for this study was performed carefully and consistently to decrease chances of test results being affected by variables such as motor learning.

Main study results

Thirty-six Division I female athletes were screened for study participation, consented to participate, and met inclusion criteria. One subject was excluded due to an injury preventing her from practicing or participating in competition. Therefore, data were

collected on thirty-five female subjects, of whom seventeen were basketball team members and eighteen were volleyball team members. Eleven of these athletes (31.4%) sustained a time-loss injury. Of these, six subjects (17.1%) sustained an injury resulting in > 50 hours of lost-time (practice, competition, or strength and conditioning time loss) due to a lower quarter injury. The mean number of hours lost due to injury was 20.6 ± 47.4 hours. Competition exposure time mean values were 326.8 ± 293.7 minutes and 62.6 ± 34.4 minutes for basketball and volleyball players, respectively (Table 2).

Descriptive Statistics for the Functional Screening Tests

The mean composite YBT scores, adjusted for limb length, were $2.471 \pm .164$ for the right and $2.503 \pm .167$ for the left lower extremity. Those who experienced lower quarter injury (LQI) scored $2.501 \pm .148$ and $2.463 \pm .148$ for their left composite YBT and right composite YBT, respectively, while those who did not experience LQI scored $2.493 \pm .210$ for the left and $2.488 \pm .202$ for the right.

Mean score for all subjects' FMS™ test was 14.9 ± 1.7 , with the mean for those with LQI being 14.6 ± 1.6 and those without LQI being 15.4 ± 1.9 . Mean scores for the SLH were 50.7 ± 7.7 inches on the left and 50.5 ± 7.7 inches on right. Those who experienced LQI scored 50.8 ± 6.3 inches on the left and 50.8 ± 7.1 inches on the right, while those who did not experience LQI scored 50.8 ± 10.4 inches on the left and 49.8 ± 9.3 inches on the right (Table 3).

P-values used to test statistical significance of differences in test scores amongst those with and without LQI ranged from .030 to .981. The only p-value that allowed the authors to reject the null hypothesis was the hurdle step component of the FMS™ test. The hurdle step component's p-value was 0.030. In this case, a higher score on the hurdle step test was more predictive of injury. Raw individual scores of those athletes who were injured are listed along with their injury diagnosis as reported by the college's sports medicine staff (Table 4).

Predictive validity of FMS™ components

High true positive rates were observed for Squat, Hurdle Step, Inline Lunge, and Rotary Stability

Table 1. Pre-testing data: *p*-values in the "Reliability" column of table 1.1 assess the null hypothesis that the intraclass correlation coefficient (formula 2,1; ICC_{2,1}) is 0.

Reliability		
Cohen's K +/- Standard Error	ICC_{2,1}	p-value
.739 +/- .212	N/A	.007
1.00	N/A	.014
1.00	N/A	.014
1.00	N/A	.014
1.00	N/A	---
.700 +/- .241	N/A	.024
1.00	N/A	---
.760 +/- .203	N/A	.002
N/A	.963 (.763-.995)	<.001
N/A	.967 (.784-.995)	<.001
N/A	.878 (.368-.982)	.005
N/A	.945 (.662-.992)	.001
N/A	.950 (.692-.993)	<.001
N/A	.435 (.000-.992)	.165
N/A	.948 (.682-.993)	.001
N/A	.820 (.172-.973)	.012
N/A	.976 (.843-.997)	<.001
N/A	.971 (.811-.996)	<.001

(Table 5). A high true negative rate was observed for Straight Leg Raise. However, positive and negative likelihood ratios all included 1.0, suggesting lack of predictive value for any FMS™ component

to predict the incidence of a lost-time injury. There was a significant association between Hurdle Step score and hours lost due to injury ($p < .05$), but not other FMS™ components.

Table 2. Subject demographics, injury incidence, and competition exposure.	
Gender	35 female (100.0%)
Sport	17 basketball (48.6%) 18 volleyball (51.4%)
Incidence of lost time injury	11 (31.3%)
Lost time due to injury (hours)	20.6 ± 47.4
Mean competition exposure time (minutes)	Basketball: 326.8 ± 293.7 Volleyball: 62.6 ± 34.4

DISCUSSION

The purpose of this study was to investigate the efficacy of three commonly used neuromuscular screening tests to predict lower quarter injury in a homogenous population of female collegiate basketball and volleyball athletes. Although the authors hypothesized that one or more single tests or a cluster of these test would accurately predict occurrence of these lower quarter injuries, there were no significant relationships between occurrence of a lost-time LQI and YBT, FMS™ composite/component, or SLHT scores. This finding suggests that none of these tests showed strong predictive ability in this cohort of women's collegiate volleyball and basketball players.

Initial research published prior to conducting the study reported that these screening tests were accurate in predicting lumbar, hip, knee or ankle injuries.^{10-12,14,16-18} However, since this study was

Table 3. Descriptive statistics: Functional Movement Screen™ (FMS™) total score, Y-Balance Test (YBT), and Single Leg Hop Test are expressed as mean ± standard deviation. Functional Movement Screen™ component scores are expressed as median (interquartile range). p-values in the "Functional Screening Performance" column are the result of Pearson Chi-square (categorical variables) or one-way ANOVA (continuous variables) to test the null hypothesis that screening measurements are the same between subjects with and without any lost-time lower quarter injury (LQI).

Functional Test		Functional Screening Performance			
		All (n=35)	LQI (n=11)	No LQI (n=24)	p-value
Squat		1 (1)	2 (1)	1 (1)	.832
Hurdle Step		2 (0)	2 (0)	2 (0)	.030*
Inline Lunge		2 (0)	2 (0)	2 (0)	.729
Shoulder Mobility		3 (1)	3 (1)	3 (1)	.554
Straight Leg Raise		3 (0)	3 (0)	3 (0)	.656
Push-up		2 (2)	1 (0)	1 (0)	.594
Rotary Stability		2 (0)	2 (2)	1 (2)	.220
FMS Total		14.9 ± 1.7	15.4 ± 1.9	14.6 ± 1.6	.243
YBT Anterior (Adjusted)	R	.504 ± .067	.513 ± .063	.500 ± .069	.589
	L	.505 ± .061	.517 ± .069	.500 ± .058	.467
YBT Posterolateral (Adjusted)	R	1.02 ± .070	1.02 ± .076	1.02 ± .069	.922
	L	1.03 ± .077	1.01 ± .092	1.04 ± .069	.317
YBT Posteromedial (Adjusted)	R	.949 ± .081	.956 ± .101	.946 ± .072	.749
	L	.967 ± .079	.966 ± .093	.968 ± .074	.872

Table 3. (continued) Descriptive statistics: Functional Movement Screen™ (FMS™) total score, Y-Balance Test (YBT), and Single Leg Hop Test are expressed as mean ± standard deviation. Functional Movement Screen™ component scores are expressed as median (interquartile range). p-values in the "Functional Screening Performance" column are the result of Pearson Chi-square (categorical variables) or one-way ANOVA (continuous variables) to test the null hypothesis that screening measurements are the same between subjects with and without any lost-time lower quarter injury (LQI).

Functional Test		Functional Screening Performance			
		All (n=35)	LQI (n=11)	No LQI (n=24)	p-value
YBT Right		2.471 ± .164	2.488 ± .202	2.463 ± .148	.676
YBT Left		2.503 ± .167	2.493 ± .210	2.501 ± .148	.818
SLH Test	R	50.5 ± 7.7	49.8 ± 9.3	50.8 ± 7.1	.735
	L	50.7 ± 7.7	50.8 ± 10.4	50.8 ± 6.3	.981

conducted, more recent research has questioned the predictive ability of these individual tests. Whitaker et al published a systematic review in 2016 investigating movement quality (15 out of 17 studies used FMS™ as the screening tool) and association with sport and occupational LE injury.¹⁹ Based upon the quality of the individual studies included and mixed findings across studies, they reported that there was inconsistent evidence that poor movement quality was associated with increased risk of LE injury.¹⁹ Two additional articles published in 2015^{8,20} studying a similar population to the one in the current study, also showed similar results. The first article²⁰ investigated the FMS™ and found the FMS™ composite score to be a poor predictor of injury in a cohort of 167 male and female Division I collegiate athletes, with data collected across basketball, football, volleyball, cross country, track and field, swimming and diving, soccer, golf, and tennis athletes.²⁰ In

the current study, qualitative factors for the FMS™ screening tests were analyzed. Poor movement quality as defined by a lower score on the FMS™, did not show increased risk of injury in this cohort of basketball and volleyball players. The second of the previously mentioned studies investigated the YBT⁸ and the authors reported that composite reach score was not associated with non-contact injury in Division I collegiate athletes. The current study also examined the relationship between YBT composite scores and injury occurrence and found the YBT was not able to predict lower quarter injury. Lastly, the authors of this study found that differences between limbs during the SLH test were not associated with lower quarter injury occurrence. This study's findings are paralleled by a recent article,²¹ where Brumitt et al found a lack of association between the SLH test and lower quadrant noncontact injury in a population of male collegiate basketball players.²¹

The results from this study, and other published research, suggest that physical functional screening tools may have limited utility in identifying women's collegiate basketball and volleyball athletes who are at increased risk of lower quarter injury. It is possible that these tests, when used in conjunction with history findings such as previous history of injury,²² or other psychosocial variables, such as reports of increased stress,²³ may more accurately predict injury in athletes who participate in these sports. Teyhen et al performed a study with 320 subjects all of whom were US Army Rangers.²⁴ Interestingly, they found that smoking, prior surgery, recurrent prior musculoskeletal injury, limited-duty days in the prior year for musculoskeletal injury, asymmetrical ankle dorsiflexion, pain with FMS clearing tests, and decreased performance on the two-mile run and two-minute sit-up test were associated with increased injury risk. Though the population in their study is distinct from those subjects included in the current study, it highlights the potential that other factors could have similar or stronger predictive value in predicting lower quarter injury when compared with neuromuscular screening tests.

Bahr, et al has suggested that sports injury screening tests have the tendency to provide limited predictive ability due to a number of factors.²⁵ One of such factors is that sports injury screening tests are scored

Table 4. Raw scores of the injured athletes with a description of each injury diagnosis. Scores are listed for the Y-Balance Test, Functional Movement Screen™, and Single Leg Hop Test.

Subject Identification Number	YBT Adjusted Composite		YBT Adjusted Anterior Reach		FMS Composite	SLH		Injury Diagnosis
	L	R	L	R		L	R	
1	2.487	2.521	0.387	0.411	17	59	54.5	Acute onset knee pain with lateral meniscus tear findings
10	2.253	2.318	0.46	0.444	14	43.5	36	Ankle sprain
19	2.19	2.222	0.492	0.522	13	41.5	44.5	Acute onset knee pain with medial meniscus tear findings
21	2.213	2.157	0.438	0.41	16	43	38	Hip Flexor Strain and Non-specific unilateral knee pain
22	2.766	2.729	0.614	0.573	18	63.5	59	Non-specific unilateral knee pain
25	2.503	2.471	0.591	0.555	15	46	49.5	Ankle sprain
27	2.411	2.426	0.547	0.537	16	35.5	44	Non-specific unilateral knee pain
30	2.523	2.443	0.523	0.531	17	52	51.5	Toe fracture
32	2.757	2.746	0.582	0.548	17	49	47	Complete tear of ACL
33	2.602	2.648	0.52	0.515	14	68.5	67	Foot sprain
34	2.718	2.691	0.536	0.596	14	58	55.5	Ankle sprain

on a continuous scale. A continuous scale and the inherent nature of athlete scoring on these tests create overlap between those who do not get injured and those who do. So while there could be some associations between a screening test and injury occurrence, athlete-screening tests typically are not able to identify those who are likely to get injured from those who are not. Perhaps this notion explains the low predictive ability of these tests in this study's cohort.

Strengths of this study include that the tests used can be easily reproduced in clinical practice. The YBT was purposefully performed without the YBT kit.

This variation can cause considerable differences in the measurements obtained for the anterior reach part of the test;²⁶ however, it was purposefully performed without using the kit to improve the external validity of study results (typically performed without the kit in clinical practice). Another strength of this study was that each of the functional tests were reliable, similar to findings of previous authors.^{14,17,27-29}

The main limitation of this study was the number of subjects included, increasing potential for a type II error, though the sample demonstrated adequate power, indicating sufficient number of subjects and a large percentage in this study who sustained

Table 5. Clinometric properties of Functional Movement Screen (FMS™) components to predict lost-time injury incidence in intercollegiate female basketball and volleyball players if FMS™ score < 3. Parenthetical values are 95% confidence intervals.

FMS Component	Sensitivity	Specificity	Positive Likelihood Ratio	Negative Likelihood Ratio	Positive Predictive Value	Negative Predictive Value
Squat	90.9% (58.7-99.8%)	4.2% (0.1-21.1%)	0.95 (0.77-1.16)	2.18 (0.15-31.77)	30.3% (15.6-48.7%)	50.0% (1.3-98.8%)
Hurdle Step	81.8% (48.2-97.7%)	0.0% (0.0-14.3%)	0.82 (0.62-1.08)	---	27.3% (13.3-45.5%)	0.0% (0.0-84.2%)
Inline Lunge	81.8% (48.2-97.7%)	12.5% (2.7-32.4%)	0.94 (0.68-1.28)	1.45 (0.28-7.50)	60.0% (14.7-94.7%)	60.0% (14.7-94.7%)
Shoulder Mobility	27.3% (6.0-61.0%)	62.5% (40.6-81.2%)	0.73 (0.24-2.17)	1.16 (0.72-1.87)	25.0% (5.5-57.2%)	65.2% (42.7-83.6%)
Straight Leg Raise	18.2% (2.3-51.8%)	87.5% (67.6-97.3%)	1.45 (0.28-7.50)	0.94 (0.68-1.28)	40.0% (5.3-85.3%)	70.0% (50.6-85.3%)
Push Up	63.6% (30.8-89.1%)	29.2% (12.6-51.1%)	0.90 (0.54-1.50)	1.25 (0.46-3.39)	29.2% (12.6-51.1%)	63.6% (30.8-89.1%)
Rotary Stability	100.0% (71.5-100.0%)	0.0% (0.0-14.3%)	1.00	---	31.4% (16.9-49.3%)	---

a time-loss injury (roughly one third). Further, the results seem to concur with those found in other published research as mentioned. Additional limitations of this study include omission of other causative variables, such as previous history of injury, which may have contributed to the potential for predicting injury in this cohort. Moreover, injury mechanism was not tracked. Epidemiological data shows that contact and non-contact injuries occur at different rates.³ In theory, functional screening tests may better predict sports injury when the injury results from a non-contact mechanism, rather than by contact. Another limitation of this study is the large amount of variance seen in competition exposure time. With greater exposure time, there are a greater number of occasions for injury to occur.^{1,3} Future research on this subject matter should consider including each of the previously mentioned limitations to help determine causative factors for sports injury.

The underlying goal of all injury screening is to reduce the occurrence of injury. Being able to detect those at increased risk of injury would theoretically help clinicians target interventions to prevent injury in those at risk individuals. Future research should continue to investigate whether physical tests, for instance landing mechanics,³⁰ or other factors such as joint laxity, and hamstring to quadriceps strength ratios,³¹ may help predict lower quarter injury in this population. Additional studies should investigate whether personal factors, (such as previous injury history and psychosocial factors) have predictive ability for lower quarter injury.

CONCLUSION

The results of this study indicate that the FMS™, SLH, and YBT were not predictive of lower quarter injury occurrence in a group of female collegiate volleyball and basketball players. Clinicians

who are attempting to identify who within a group of physically active people are at increased risk of injury should consider that the performance on the YBT, FMS™, and SLH alone might not accurately identify at risk individuals in female basketball and volleyball players. Clinicians should also consider that information from physical tests, in combination with other variables, such as personal factors, might have added predictive ability for injury occurrence. Clinicians using injury screening tools should consider the available evidence on validity of such tools. Future research should compare a wider range of physical variables, as well as non-physical factors that may be able to more accurately identify those at increased risk for injury.

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