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Examining the association of injury with the Functional Movement Screen and Landing Error Scoring System in military recruits undergoing 16 weeks of introductory fitness training.

Short Title: Examining the association of injury with the Functional Movement Screen and Landing Error Scoring System in military recruits

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Objective: To examine the association of injury with the Functional Movement Screen (FMS) and Landing Error Scoring System (LESS) in military recruits undergoing an intensive 16-week training block.

Design: Prospective cohort study

Methods: One hundred and thirty-two entry-level male soldiers (18-25 years) were tested using the FMS and LESS. The participants underwent an intensive 16-week training program with injury data recorded daily. Chi-squared statistics were used to examine associations between injury risk and (1) poor LESS scores, (2) any score of 1 on the FMS and (3) composite FMS score of ≤ 14 .

Results: A composite FMS score of ≤ 14 was not a significant predictor of injury. LESS scores of > 5 and having a score of 1 on any FMS test were significantly associated with injury. LESS scores had greater relative risk, sensitivity and specificity (2.2 (95% CI= 1.48-3.34); 71% and 87% respectively) than scores of 1 on the FMS (relative risk = 1.32 (95% CI= 1.0-1.7); sensitivity =50% and specificity = 76%).

Conclusions: There was no association between composite FMS score and injury but LESS scores and scores of 1 in the FMS test were significantly associated with injury in varying degrees. LESS scores had a much better association with injury than both any scores of 1 on the FMS and a combination of LESS scores and scores of 1 on the FMS. Furthermore, the LESS provides comparable information related to injury risk as other well-established markers associated with injury such as age, muscular strength and previous injury.

Keywords: LESS, FMS, Injury Risk, Pre-participation screening, Testing, Functional screening.

INTRODUCTION

Musculoskeletal (MSK) injuries are among the leading causes of morbidity in both sport and military settings (1-4). The impact of MSK injury ranges from limiting training to complete withdrawal from military service and sports participation (2, 3). In the United States military, nine hundred thousand recruits are affected by MSK injury per year, resulting in 2.4 million medical visits at an estimated cost of \$548 million (3,4). In the United Kingdom, the incidence of MSK injury during military training ranges from 20-59% with 8% of these injuries resulting in full discharge of service (5).

With such negative and costly consequences associated with MSK injury, it is no surprise that much research examining how to reduce the incidence of MSK injury has been published (1, 3, 5). One proposed method of reducing injury is through the assessment of fundamental movement patterns (6). Fundamental movement patterns are described as basic movement patterns that require adequate joint range of motion, core stability and overall balance in various body positions to facilitate the successful completion of both physical training and activities of daily living (6). It is proposed that dysfunctional movements during these fundamental movement patterns predispose individuals to increased chance of injury (10, 7). The most common assessment tool used to examine fundamental movement in military and sporting populations is the Functional Movement Screen (FMS) (2, 7).

The FMS is a series of seven tests that examine various levels of movement difficulty (6). While reliability of the FMS has been established (9), there are conflicting reports about its association with injury (9, 10). Several studies have reported that a composite score of ≤ 14 is associated with an increased risk of injury (10, 13, 14), however, two recent studies have reported no relationship between the composite FMS score and injury risk (12, 15). Secondly, some of the studies reporting a relationship between composite FMS score and injury risk

have reported low sensitivity, indicating that the FMS may not detect individuals who are still at risk of injury (10, 13, 14).

A potential alternative screening assessment to the FMS may be the various field-based, dynamic jump-landing tools that have recently been developed (16, 17). The Landing Error Scoring System (LESS) is one such assessment tool (16). The LESS was originally developed to identify dynamic biomechanical faults traditionally used to detect ACL injury risk (16). It has reported good inter- and intra-rater reliability (16, 18) as well as good concurrent validity with more established 3D assessment (16). However, there are conflicting results concerning its ability to directly predict ACL injury (19, 20). Furthermore, no study to date has examined whether LESS scores can predict total injuries and no prospective injury studies have been conducted using both the FMS and LESS to predict injury risk. Therefore, the aim of this study was to examine whether the FMS, LESS or a combination of both could predict injury in a group of military recruits undertaking a well-controlled, 16-week military training program.

METHODS

This investigation comprised a prospective cohort study. The local University Research Ethics Committee and Institutional Review Boards of the National Defense Forces approved all the procedures undertaken in this project. All participants were fully briefed about the study and provided written informed consent before testing.

One hundred and thirty two male entry-level military recruits (age= 22.4 ± 4.2 years; height= 1.77 ± 0.35 m; mass = 74.5 ± 5.8 kg) voluntarily participated in this study. Participants were excluded from the study if they had a current injury, medical condition or recent surgery that would compromise their ability to perform the tests or participate in the 16-week military training program.

Prior to testing, volunteers were briefed on the FMS and LESS tests and were provided with an overview of the study. Each participant filled in a health questionnaire, had key anthropometric data recorded and completed the LESS and FMS tests in a random order on the same day. Participants refrained from intensive exercise and abstained from alcohol, caffeine or any other stimulant that may influence their performance in the 24 hours prior to testing. Participants were provided with a visual demonstration of the LESS and FMS tasks and the related verbal instructions as described by Cook (6) for the FMS and Padua et al. (16) for the LESS test. The FMS and LESS tests were conducted by the principal experimenter who is a chartered physiotherapist, certified athletic therapist, certified in FMS and has conducted over 1000 FMS and LESS screens.

The FMS consists of seven tests that assess various movement patterns in an effort to identify potential physical limitations or asymmetries in these patterns. The seven tests include, the squat, hurdle step, lunge, rotary stability, shoulder mobility and active straight leg raise (ASLR) with 3 provocation tests to discount the presence of back and shoulder pain (6). Traditionally, each of the seven FMS sub-tests are scored out of three with a score of zero indicating the participant experienced pain in one of the screens or had pain in one of the clearing tests (6). A score of one is given if the participant cannot complete a screen or if they have compensations when performing an easier, modified version of the original screen (6). A participant scores a two if they can perform the original screen but have some compensations in the movement or if they can perform an easier, modified version perfectly without fault (6). Finally, a three is awarded when participant can perform the screen perfectly without compensation (6). As there are seven tests the maximum score available is 21 and the lowest possible score for an athlete not reporting pain is seven (6). A full description and detailed scoring system for the FMS is available in various sources (6, 13).

The LESS is a field-based movement screen that scores an individual's landing technique based on a set of 17 easily observable criteria (16). The LESS requires the participant to jump forward from a 30 cm box, land on a designated spot that is half their height away from the starting position and then immediately jump vertically as high as possible (16) (Figure 1). The individual's score out of 17 is inversely proportional to the LESS performance. Scoring criteria and description of the LESS has been previously provided in the research (16).

Figure 1 here

The FMS and LESS tests were recorded using a Sony HDD Handycam (DCR-SR62 hard disk drive camera, Tokyo, Japan). Both tests were recorded from the frontal and sagittal view with the exception of the shoulder mobility and ASLR tests, where only one view was deemed necessary. The camera was positioned so that participants could be fully observed during each of the FMS movement patterns and the LESS test (21). Scoring was performed the next day by the principle author. All analyses of FMS and LESS videos were completed using 2D video software (Dartfish Prosuite 5.5, Dartfish, Fribourg, Switzerland). The principle author was allowed to slow down and view the videos as many times as required to ensure accurate scoring.

The training environment was extremely well controlled. Participants remained on base for the 16 week period with identical nutrition, schedule (meal and sleep times) and training loads. Furthermore, participants were not involved in any other activity or sport during the 16 week period. There were 599.25 overall training hours with 85 formal physical training hours comprising of resistance training, aerobic exercise (primarily running), battle runs (with military gear), swimming and organized recreational training. Other training comprised of orientation, weapons training, drills, guard duties, first responder courses, unarmed combat courses and tactical training.

Time-loss MSK injury data were collected daily during the 16-week training program at the medical facility on the military base. Medical care providers, who were not part of the study, assessed participants for MSK injury and recorded injuries manually using a specialized form. For this study, an MSK injury was defined as physical damage to the body which was secondary to physical training and required medical care one or more times during the study period and resulted in at least one day of missed training (10, 22).

All data were analyzed using SPSS Statistical Software (SPSS Version 22, SPSS Inc., Chicago, IL, USA). Descriptive statistics were analyzed for LESS and FMS results. LESS scores were reported as mean \pm SD as well as 95% confidence intervals and FMS scores as median (minimum-maximum). The median score was reported rather than the mean due to FMS data being ordinal in nature (31). To examine the relationship between potential risk factors and injury, discrete and continuous variables were converted into dichotomous variables (12). For the FMS, a 'yes' was assigned for any individual with a score of 1 on any of the FMS tests and 'no' for the participants who did not have a score of 1. The composite score of 14 was also dichotomized using 14 as a cut point (>14 vs. ≤ 14). Using a cut-off score of >5 , as determined by the ROC curve analysis (19), LESS scores were dichotomized into acceptable and poor (≤ 5 vs. >5) (19). Pearson's Chi squared statistics were used to examine any potential associations between recruits who sustained injury and (1) had LESS scores of >5 ; (2) had a score of 1 on any FMS test and (3) had a composite FMS score of ≤ 14 . Injury was the dependent variable for each analysis. Finally, ROC curves were utilized to determine the optimal cut-point for both composite LESS and FMS scores in predicting MSK injury.

RESULTS

The median FMS score was 15 (11-20) and the mean LESS score was 4.76 (\pm 2.71). Twenty eight injuries were sustained during the 16-week training program. A summary of all injuries sustained and the severity of each injury is presented in Table 1. The number of participants who scored ≤ 14 , who had a score of 1 in any FMS test or had a score of >5 in the LESS were 42,39 and 34 respectively.

Table 1 here

The main findings were that composite FMS scores of ≤ 14 were not associated with an increased risk of injury (Table 2). However, scores of 1 in the FMS and poor LESS scores were associated with a greater proportion of injury (FMS Scores of 1 Odds Ratio = 3.16 (95% CI= 1.32-7.5 ; $p < .01$); LESS Odds Ratio = 16.07 (95% CI= 5.94-43.45); $p < .01$). Using the contingency values outlined in table 2, sensitivity and specificity were calculated at 73% and 87% respectively for LESS scores with a relative risk of 2.2 (95% CI = 1.48-3.34). For scores of 1 on the FMS, the sensitivity and specificity were 50% and 76% respectively with a relative risk of 1.32 (95% CI= 1.0-1.7, Table 2). Participants with poor LESS scores and a score of 1 had a significant increased association with injury but the association was not larger than poor LESS scores only (Table 2). Table 3 outlines the relationship between the LESS, FMS scores and the location and severity of the injuries sustained.

Finally, the ROC curves for FMS scores were not significant (area under the curve = .433) but the LESS had a significant ROC curve (area under the curve = .761) with a maximized specificity cut-point score of 5.5 and sensitivity and specificity values of 73% and 75% respectively (Figure 2). This specificity cut-point is what determined the cut off score of > 5 to be used in this study.

Table 2 and 3 here

Figure 2 here

DISCUSSION

The main findings of this study were that composite FMS score was not significantly associated with injury but a poor LESS score (> 5) and having a score of 1 on any FMS test were associated with injury in a military cohort undergoing an intensive, 16-week military training program (Table 2). Poor LESS scores had a much greater association with injury than either scores of 1 on any FMS test or scores of 1 and LESS scores combined (Table 2). Furthermore, the specificity and sensitivity figures for the LESS test were also high compared to other established markers associated with injury such as age, previous injury and aberrant movement patterns (23), indicating that the LESS provides similar information to other well established markers associated with injury.

Due to the relatively small number of injuries it was deemed inappropriate to perform statistical analysis examining the relationship between the LESS, FMS and the severity and location of injury (Table 3) (31). However, as outlined in table 3, the LESS had the greatest association with lower limb injuries. Of the 34 participants who scored poorly on the LESS, 10 (29%) sustained an injury to the knee, 3 sustained an ankle injury and 4 had lower limb injuries. In contrast, only 3% of the 98 participants with acceptable LESS scores (≤ 5) sustained a knee injury and there was only one ankle and lower limb injury in this group. Furthermore, poor LESS scores identified all 3 (100%) of the severe injuries (injury serious enough to jeopardize completion of training program), 56% (5 out of 9) of the moderate injuries (injury requiring at least 7 days rest and substantial medical treatment) and 12 out of 16 (75%) of the mild injuries (injury resolving within 7 days and little medical intervention required) sustained in this cohort. In contrast, any score of 1 on the FMS or combining FMS and LESS scores did not have as strong an association with injury, in particular scores of 1 on

the FMS were only associated with only 1 of the 3 severe injuries and 3 of the 9 moderate injuries sustained in this cohort (Table 3).

The finding that composite FMS score or scores of ≥ 14 were not associated with injury contradicts previous research in both sports (13, 14) and military settings (10). However, this finding is supported by two recent studies that have reported no relationship between composite score and injury risk (12, 15). There are a number of reasons for the lack of association between composite FMS score and injury risk. First, the creators of the FMS have stated that composite FMS score was never intended as a means of predicting injury, but rather it was intended to identify severe limitations (i.e. scores of 1) in certain movement patterns (24). This theoretical framework is supported by two studies that have undertaken factorial analyses of the seven FMS test components and reported poor internal consistency between the tests (25, 26). This indicates that the seven individual tests measure different variables, making it statistically inappropriate to add the scores of these tests together (25).

While composite FMS scores were not associated with injury, individuals with a score of 1 on the FMS tests were 1.3 times more likely to sustain injury than those without a score of 1 (relative risk = 1.32; 95% CI= 1.0-1.7). The rationale for scores of 1 on the FMS being associated with injury is clear. The FMS was designed to assess basic movement patterns required for training and daily living (6, 13) and scores of 1 indicate that an individual cannot complete or has severe limitations in one of these basic patterns (6). The results of this study support this underlying premise that severe limitations in one or more of these basic patterns predispose individuals to injury during intensive training (Table 2). Caution is required when interpreting these results however as a sensitivity score of only 50% needs consideration. The relatively poor sensitivity in this study supports previous research highlighting that the FMS is much better at including individuals with potential injury risk than excluding those who may have less chance of injury (10, 27).

In contrast to composite FMS score, poor LESS scores of >5 were associated with over a two-fold increased likelihood of injury. In addition, good sensitivity (73%) and excellent specificity (87%) related to the LESS score indicate that the LESS is a good screening tool to identify both those who have increased and decreased risk of injury when undergoing military training. To our knowledge, this is the first study to examine the relationship between overall injury risk and LESS scores. Unsurprisingly, given it was originally designed to detect ACL risk, poor LESS scores had a strong association with knee injuries. In addition, LESS scores also had a strong relationship with total lower limb injuries sustained. Seventeen of the 22 (77%) lower limb injuries sustained in the entire cohort were with participants with poor LESS scores (>5). In contrast, from our results there does not appear to be a strong association between either upper limb or back injuries and poor LESS scores (Table 3).

The results of this study clearly indicated that the LESS had a greater association with injury than the FMS and in particular had a very strong association with lower limb injuries. The reason for this greater association may be due to the more dynamic nature of the LESS test (16). The LESS requires much more eccentric strength and dynamic control to ensure satisfactory performance (28). Several studies have argued that the low sensitivity associated with the FMS arises because it does not challenge the eccentric strength and dynamic control required during intensive training or competition (9, 27, 28). Individuals who lack these forms of strength and control may place their joints and muscles in compromised positions that are linked with the mechanisms of acute and chronic injuries (7, 29). Therefore, the increased eccentric strength and dynamic control required of the LESS may explain why this test has a better association with injury than the FMS (Table 2). Additionally, the LESS is reported to have a strong correlation with mechanical faults associated with common lower limb injuries (16). Using 3D analysis, Padua et al. (16) reported that LESS scores correlated significantly with kinematic and kinetic faults (knee valgus, limited hip and knee flexion,

internal hip rotation) associated with ACL injuries (16). Several studies utilizing similar 3D kinematic and kinetic procedures have reported relationships between these faults and various other lower limb injuries such as ankle ligament sprains, chronic knee injuries and hip impingement (29, 30). Therefore, the fact that the LESS test correlates with already established risk factors may underlie its superiority as an injury prediction tool compared to the FMS.

While the main findings of this study are clear, there were some limitations with this research. First, 132 participants, while substantive, is a relatively smaller cohort compared to other larger military prospective studies (9,10). Second, this study examined military recruits during introductory fitness training. This limits the ability to generalize the results and so it is unclear whether a sporting population would respond similarly. Finally, due to the relatively small number of injuries sustained in this study the authors' deemed it inappropriate to perform further analysis to examine the relationship between FMS or LESS scores and different sub-categories of injury (location, severity, onset etc.). Future large scale studies are required to help answer this question.

CONCLUSION

The results of this study do not advocate the use of composite FMS score as an injury prediction tool but did find that LESS scores and scores of 1 in the FMS test were significantly associated with injury. The LESS screen had a much better association with injury than both scores of 1 on the FMS and a combination of LESS scores and scores of 1 on the FMS. Furthermore, the LESS provides comparable information related to injury risk as other well-established markers associated with injury (i.e. age, muscular strength, previous injury) (7, 23). Caution is advised when using the FMS on its own as an injury prediction tool as a sensitivity score of 50% indicates a large proportion of recruits without scores of 1 on the

FMS may still have a high risk of injury. Future studies should examine the ability of these screens to predict injury in sporting populations and further examine why the LESS is a better predictor of injury than the FMS by examining each test against more established 3D assessment methods.

Practical Implications

- LESS is a significant predictor of overall injury risk during military training
- Composite FMS score was not a significant predictor of injury
- A score of 1 on the FMS was a significant predictor of injury risk
- LESS had a greater association with injury than a score of 1 on the FMS
- Combining LESS and FMS did not improve the precision of injury prediction.
- Poor LESS scores was associated with 77% of the lower limb injuries sustained in this cohort.

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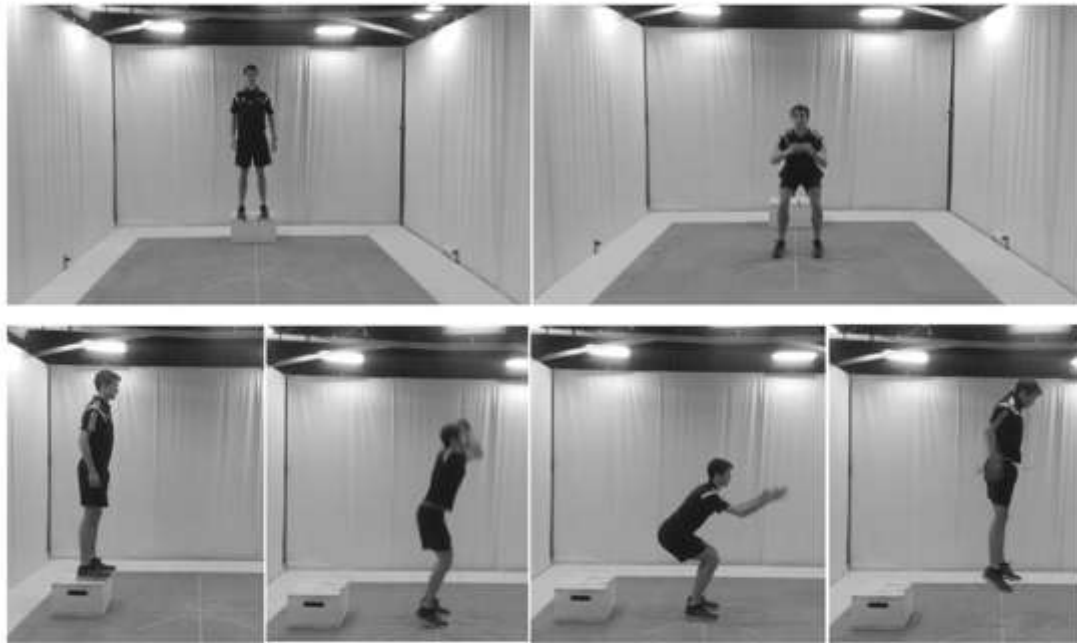
Figure 1- Demonstration of Landing Error Scoring System

Fig 2

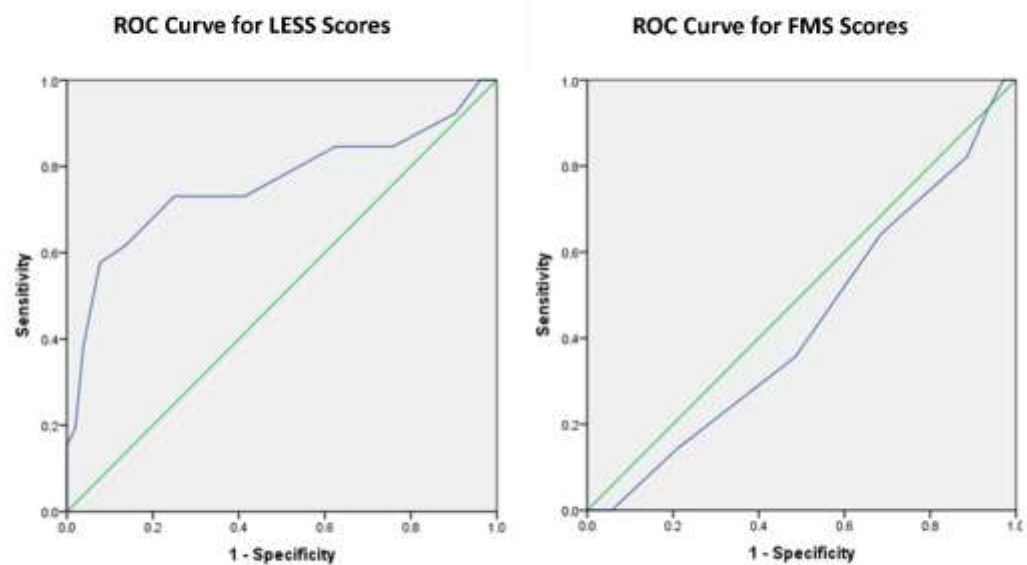


Table 1- Summary of injury statistics

Factors	Classification	Frequency	Percentage
Injury Location	Knee	13	46%
	Lower Limb muscle tear	5	18%
	Ankle	4	14%
	Back	4	14%
	Shoulder	2	7%
Type of injury	Muscle strain	9	32%
	Muscle Spasm	7	25%
	Ligament	3	11%
	Tendon	9	32%
Onset	Immediate	21	75%
	Delayed	7	25%
Causative Factors	Non Contact	27	96%
	Contact	1	4%
Severity	Mild (1-7 days)	16	57%
	Moderate (7-21 days)	9	32%
	Severe (Surgery or discharge)	3	10%
Mechanism	Acute	13	44%
	Chronic	15	56%

Table 2- Injury statistics associated with military training.

	Injury (Total)	Chi Squared	Odds Ratio (95% CI)	Relative Risk (95% CI)	Sensitivity	Specificity
Scores of 1 on FMS	14 (39)	7.14	3.16 (1.32-7.5)	1.32 (1.0-1.7)	50%	76%
Poor LESS	14 (34)	38.75	16.07 (5.94-43.45)	2.2 (1.48-3.34)	73%	87%
Poor LESS and Score of 1	11 (19)	17.87	7.76 (2.7-22.11)	2.01 (1.18-3.4)	57%	85%
Scores of ≤ 14	10 (42)	0.249 (NS)	1.25(0.52-3.0)	1.05(0.86-1.2)	23%	77%

*CI= Confidence Intervals; NS=Not Significant

Table 3- Location and Severity of Injury

Variable	No Injury (Total participants)	Location of Injury					Severity of Injury		
		Ankle (TI)	Knee (TI)	Lower-limb (TI)	Back (TI)	Shoulder (TI)	Mild (TI)	Moderate (TI)	Severe (TI)
FMS	24 (39)	0 (4)	9 (13)	2 (5)	2 (4)	1 (2)	9 (16)	4 (9)	1 (3)
Score of 1									
Poor LESS (>5)	14 (34)	3 (4)	10 (13)	4 (5)	2 (4)	1 (2)	12 (16)	5 (9)	3 (3)
Poor LESS and Score of 1	8 (19)	0 (4)	7 (13)	2 (5)	1 (4)	1 (2)	7 (16)	3 (9)	1 (3)

TI= Total Injuries