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Human Kinetics
TECHNICAL REPORT

Examining the Reliability of the Landing Error Scoring System With Raters Using the Standardized Instructions and Scoring Sheet

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Context: Dynamic movement-based screens, such as the Landing Error Scoring System (LESS), are becoming more widely used in research and practical settings. Currently, 3 studies have examined the reliability of the LESS. These studies have reported good interrater and intrarater reliability. However, all 3 studies involved raters, who were founders of the LESS. Therefore, it is unclear whether the reliability reported reflects that which would be observed with practitioners without such specialized and intimate knowledge of the screen and only using the standardized set of instructions. ***Objective:*** To investigate the interrater and intrarater reliability of the final score and the individual scoring criteria of the LESS. ***Design:*** Reliability protocol. ***Setting:*** Controlled laboratory. ***Participants:*** Two raters scored 30 male participants (age = 21.8 [3.9] y; height = 1.75 [0.46] m; mass = 75.5 [6.6] kg) involved in a variety of college sports. ***Main Outcome Measure:*** Two raters using only the standardized scoring sheet assessed the interrater reliability of the total score and individual scoring criteria independently of each other. The principal author scored the videos again 6 weeks later for the intrarater reliability component of the study. ***Intervention:*** Participants performed a drop box landing from a 30-cm box was recorded with a video camera from the front and side views. ***Results:*** The intraclass coefficients interrater and intrarater reliability for the total scores were excellent (intraclass coefficients range = .95 and .96; SEM = 1.01 and 1.02). The individual scoring criteria of the LESS had between moderate and perfect agreement using kappa statistics (κ = .41–1.0). ***Conclusion:*** The final score and individual scoring criteria of the LESS have acceptable reliability with raters using the standardized scoring sheet. Practitioners using only the standardized scoring sheet should feel confident that the LESS is a reliable tool.

Keywords: screening, LESS, drop jump, dynamic screen, movement screen

Preparticipation testing has become an established process of identifying potential risk factors that may predispose athletes or active individuals to injury.[1,2] Preparticipation testing has traditionally included flexibility tests and assessments of isolated muscle strength[1,2]; however, more recently, there has been an increasing emphasis on movement screening as the main element of preparticipation testing.[3,4] Movement screening involves assessing an athlete's movement patterns during various movements and providing a discernible score.[4,5] Assessing movement patterns is of paramount importance, as it is a modifiable risk factor that may predispose athletes to injury.[6]

The Landing Error Scoring System (LESS) is becoming a popular dynamic field-based screen in the practical and research settings.[6–8] The LESS is a modified drop jump that requires practitioners to examine faults from the front and side views. The scoring criteria for the LESS have been derived from previous research that have identified specific movements which may contribute to increased risk of injury, in particular anterior cruciate ligament (ACL) injury.[6]

Studies examining the association of injury and LESS scores have reported that poor LESS scores were significantly associated with lower-limb injury and ACL injury in military and sporting populations.[7,8] Padua et al[6] reported that LESS scores also have a significant association with 3D kinematics of a drop jump. 3D kinematics have been reported by the Olympic Committee as a gold standard assessment for lower-limb injuries, in particular acute knee injury.[6] These studies are encouraging, as they highlight a practical value to using the LESS as an injury prediction tool. However, before validity studies are developed, it is important that reliability of the LESS be established.[9]

Three studies have examined the reliability of the LESS, with all 3 reporting good intrarater and interrater reliability.[6,10,11] Despite the positive reliability reported, there are several limitations with these 3 studies that require investigation. All 3 studies involved raters, who were founders of the LESS. The reliability reported may be high in these studies due to the intimate knowledge the founders would have of the screen. Therefore, it is unclear whether the reliability of the LESS would be similar in raters using only the standardized set of instructions. Furthermore, only the study by Onate et al[11] examined the reliability of the individual scoring criteria. Examining only the final score may overestimate the reliability of the LESS, as it fails to account for 2 raters scoring the individual criteria differently but still totaling the same final score.[11]

The aim of this study is to examine the reliability of the final score and individual criteria of the LESS when scored by 2 raters using only the standardized instructions and scoring sheet. This will provide insight to those who can only use the standardized scoring sheet whether the LESS is a reliable screen to use in the rehabilitation setting.

Methods

Participants

A total of 30 male participants (age = 21.8 [3.9] y; height = 1.75 [0.46] m; mass = 75.5 [6.6] kg) involved in a variety of college sports (Gaelic games, n = 10; soccer, n = 6; boxing/mixed martial

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arts, n = 2, Olympic weight lifting, n = 8, and track and field, n = 4]) at a college level participated voluntarily in this study. The participants in this study were part of a larger study involving college participants, who competed at intervarsity level and trained at least twice per week with their respective teams. The participants for this study were chosen at random from the larger study.

The 2 raters were a chartered physiotherapist with an MSc in physiotherapy, and a strength and conditioning specialist with an MSc in strength and conditioning. Both raters had 4 years of experience in biomechanical assessments and had conducted over 200 functional movement screen (FMS) assessments, but they had little experience with the LESS. Both raters used the instructions and scoring sheet as outlined by Padua et al[6] to score the LESS. The raters scored the videos independently. The videos were rescored 6 weeks later by the first rater. Due to time restraints, only the first rater (chartered physiotherapist) undertook the intrarater reliability element of this study.

The University of Limerick research ethics committee approved all procedures undertaken in this study. All participants received appropriate explanation of the study, including the benefits and risks of participating. We obtained informed written consent from all participants before testing commenced. All participants were required to be 18 years or older, actively involved in sport (>twice per week, formalized training or competition) for over a year, with no medical condition that would compromise participation in the study.[12] Similar to criteria set out by Chorba et al,[13] participants were excluded from the study, if they had sustained an injury that prohibited them from training or competition in the previous 30 days or had recent surgery that limited athletic participation. This was undertaken to limit the influence that a recent injury may have on screening scores.[12,13]

Procedure

Landing Error Scoring System. The LESS is a screening assessment that scores an individual's landing technique based on a set of 17 criteria that are easily observable to the human eye.[6] The task involves a participant jumping forward from a 30-cm box, landing on a designated spot that is a distance equal to half their height away from the starting position, and then immediately jumping vertically as high as they can (Figure 1).[6]

The scoring criteria for the LESS have been derived from previous research that have identified specific movements which may contribute to increased risk of injury, in particular ACL injury.[6] The 17 criteria (Table 1) examine lower-extremity and trunk motion in the frontal and sagittal planes from initial ground contact, until the participant jumps again vertically and can be subdivided into 3 main categories. The first category scores the jump-landing technique in relation to trunk and lower-extremity position at the time of initial ground contact. The second category scores any faults associated with the feet between the point of contact with the ground and the time of maximum knee flexion. The third category scores trunk and lower-extremity movements between the point of initial ground contact and the time of maximum knee flexion. The final 2 scoring criteria require the examiner to judge the amount of overall sagittal plane movement at

Figure 1 — Demonstration of the landing error scoring system test.

Table 1 Scoring of the Landing Error Scoring System

1. Knee flexion @ initial contact > 30 degrees ___ Yes (0) ___ No (1)	10. Stance width @ Initial Contact > Shoulder width ___ Yes (1) ___ No (0)
2. Knee Valgus @ Initial Contact: Knee over midfoot ___ Yes (0) ___ No (1)	11. Initial Foot Contact: Symmetric ___ Yes (0) ___ No (1)
3. Hip Flexion @ Initial Contact: Hips are flexed ___ Yes (0) ___ No (1)	12. Knee flexion Displacement: >45 degrees ___ Yes (0) ___ No (1)
4. Trunk Flexion @ Initial Contact: Trunk is flexed ___ Yes (0) ___ No (1)	13. Knee Valgus Displacement ≥Great toe ___ Yes (1) ___ No (0)
5. Lateral Trunk Flexion@ Initial Contact: Trunk is vertical ___ Yes (0) ___ No (1)	14. Hip Flexion Displacement: Hips flex more than @ initial contact ___ Yes (0) ___ No (1)
6. Ankle Plantar Flexion @ Initial Contact: Toe to heel ___ Yes (0) ___ No (1)	15. Trunk Flexion Displacement: Trunk Flexion more than @ initial contact ___ Yes (0) ___ No (1)
7. Foot Position @ Initial Contact: Toes >30 ER ___ Yes (1) ___ No (0)	16. Joint Displacement (Sagittal Plane) ___ Soft (0) ___ Average (1) ___ Stiff (2)
8. Foot Position @ Initial Contact IR present ___ Yes (1) ___ No (0)	17. Overall Impression ___ Excellent (0) ___ Average (1) ___ Poor (2)
9. Stance Width @ Initial Contact < Shoulder width ___ Yes (1) ___ No (0)	

Abbreviations: IR = internal rotation; ER = external rotation.

the hips and knee from initial ground contact to maximum knee flexion angle and to provide an overall impression of jump technique (Table 1).

Data Collection and Scoring the LESS

The LESS tests were recorded using a Sony HDD handycam (DCR-SR62 hard disk drive camera; Sony, Tokyo, Japan). Frontal and sagittal view recordings were obtained for all tests. LESS videos were analyzed using 2D video software (Prosuite 5.5; Dartfish, Fribourg, Switzerland). The raters were allowed to view the videos as many times as possible and as slow a speed as required to provide an accurate score. The raters scored the LESS using the standardized scoring sheet outlined in Padua et al.[6] The raters had to score the LESS tests independently of each other. Six weeks after the first assessment, the first rater rescored the LESS videos, which were played in a random order to prevent recall bias.

Statistical Analysis

SPSS (version 22; SPSS Inc, Chicago, IL) was used for all statistical analysis performed. Interrater and intrarater reliability of the test scores were analyzed using intraclass coefficients (ICCs) with 95% confidence intervals (CIs). Absolute reliability was determined through examining SEM of the final score of the LESS. Kappa statistics with 95% CI were conducted for the individual scoring criteria of the LESS. Kappa statistics were chosen due to the analysis being stronger than calculating percentage agreement between raters.[14] Kappa statistics take the chance of random agreement into account.[14] Using criteria described by Sim and Wright,[14] reliability was classified as follows: excellent agreement between raters when Kappa scores were 80% and higher. Kappa scores of 60% to 79.9% represent substantial agreement and scores of 40% to 59.9% equate to moderate agreement. Finally, Kappa scores below 40% represent fair to poor agreement.[14] Using ICC, values between .75 and 1 represent good reliability, values between .50 and .74 equate to moderate reliability, and values below .50 are deemed to have poor reliability.[15]

Results

For the total score of the LESS, the interrater and intrarater ICC values were .95 (95% CI, 0.90–0.97; $P > .001$) and .96 (95% CI, 0.93–0.98; $P > .001$), respectively, indicating that the LESS had almost perfect interrater and intrarater reliability. The SEM for the interrater and intrarater reliability was 1.01 and 1.02, respectively. With regards to the individual scoring criteria, Tables 2 and 3 highlight that all the individual scoring criteria had between perfect and moderate agreement with Kappa statistics and ICC values.

Discussion

The main findings of our study were that the LESS screening protocol had acceptable interrater and intrarater reliability. Final score for the LESS had excellent interrater and intrarater ICC values of over .90, indicating that final scores of the LESS are reliable. The ICC scores reported in our study are comparable to other reliability studies involving the LESS tests.[6,10,11] These

Table 2 Interrater and Intrarater Kappa Statistics of LESS Scoring Criteria

	Knee flexion at IC	Hip flexion at IC	Trunk flexion at IC	Heel to toe	Additional knee flexion	Additional hip flexion	Additional trunk flexion	Joint displacement	Knee valgus at IC	Trunk side flexion	Stance width	Foot placement	Asymmetric foot contact	Maximum knee valgus	Overall impression
Interrater*	.41	1.0	.61	1.0	.51	.53	.47	.46	.86	.49	1.00	.84	1.00	.93	.55*
Intrarater*	.63	1.0	.60	1.0	.47	.60	.55	.64	.86	.49	1.00	1.00	1.00	.87	.89*

Abbreviations: IC, initial contact; LESS, landing error scoring system.
*Significant to >.05.

Table 3 Interrater and Intrarater ICC Statistics of LESS Scoring Criteria

	Knee flexion at IC	Hip flexion at IC	Trunk flexion at IC	Heel to toe	Additional knee flexion	Additional hip flexion	Additional trunk flexion	Joint displacement	Knee valgus at IC	Trunk side flexion	Stance width	Foot placement	Asymmetric foot contact	Maximum knee valgus	Overall impression
Interrater*	.64	1.0	.75	1.0	.70	.71	.65	.82	.93	.65	1.00	.84	1.00	.94	.73
Intrarater*	.8	1.0	.75	1.0	.65	.75	.73	.88	.92	.65	1.00	1.00	1.00	.92	.96

Abbreviations: IC, initial contact; ICC, intraclass coefficients; LESS, landing error scoring system.
*Significant to >.05.

results highlight that the LESS has acceptable levels of reliability with raters using the standardized set of instructions.

This was the first study to examine reliability of the total score of the LESS with raters, who were not founders of the tool. The similar reliability reported in this study is encouraging for practitioners who use the LESS and only have the standardized instructions and scoring sheet to guide them. Our results indicate that they will have acceptable reliability using the standardized scoring criteria instructions and can be confident that the results reported would be similar each time and similar to other raters using the standardized instructions and scoring sheet.

Although the reliability of the LESS composite score was excellent, this is only a limited assessment of reliability.[14] Two raters could score individual criteria differently, but when the criteria are added up, it arrive at the same score.[3] Therefore, there is a chance that the high levels of reliability reported relating to the total scores may be due to random chance rather than consistent agreement between raters for all criteria of the LESS.[3] In this regard, the reliability of the individual scoring criteria of the LESS is more important to examine.

All individual scoring criteria of the LESS had between perfect and moderate reliability. Unsurprisingly, the scoring criteria where subjective, clinical judgment was required, such as overall impression and overall joint displacement, had the worst reliability (Table 2). There are no set criteria to determine a soft versus an average landing, but it is determined by the clinical judgment of the rater.[6] Therefore, 2 raters subjectively disagreeing on the softness of the landing may account for these criteria having the lowest reliability. In contrast, the scoring criteria, with set yes or no objective markers had perfect or almost perfect reliability. Using video analysis, it is easy to observe whether a participant keeps their feet shoulder width apart during the jump. Therefore, it is unsurprising that reliability was high with these objective scoring criteria (Table 2). However, even with the more subjective criteria, interrater and intrarater reliability of the total score and individual scoring criteria of the LESS were moderate to perfect.

Intrarater and interrater reliability scores were similar for the final score and the majority of the scoring criteria with the exception of knee flexion and joint displacement, where intrarater reliability was substantial compared with moderate reliability for interrater reliability. As mentioned previously, these measures are subjective in nature.[6] The same rater will have greater consistency in determining the subjective measures of the LESS. Practically, this helps to validate the use of intervention studies to examine exercise protocols that may improve LESS scores. Practitioners can be confident that improvements are due to changes in jump-landing mechanics.

There are several limitations that need to be addressed with this study. First, this study used 2 raters to examine reliability. Best practice would indicate that several raters examining the 30 participants would provide greater insight into the reliability of the LESS.[9] Furthermore, as the 2 raters were inexperienced with the LESS, they did have significant experience with movement analysis and scoring the FMS.[4] The FMS is a series of 7 tests that include a squat and lunge.[4] As the squat and lunge are performed at a much slower speed compared with the LESS, the scoring criteria for these 2 tests (knee valgus, hip flexion, and trunk displacement) are similar.[4] This experience with analyzing movement may have helped the raters with scoring the LESS compared with someone without prior movement experience.[16] FMS reliability studies reported that those with experience in movement mechanics had greater reliability compared with students and those who were certified in the FMS but did not have a biomechanics background.[16] Therefore, future studies should examine the influence of background and experience on LESS reliability.

Finally, this study used ICC, kappa statistics, and SEM to measure interrater and intrarater reliability. These measures were chosen to provide an absolute reliability score and to compare the reliability of the LESS with the 2 raters in this study to previous LESS reliability studies. There are many methods to assess reliability that were not included here that would have perhaps added greater insight into the reliability of the LESS.

The findings of this study have practical applications for health care practitioners, and strength and conditioning specialists involved in the rehabilitation setting. Three-dimensional (3D) kinematic analysis has long been established as the gold standard in movement analysis of dynamic actions, such as jump landing.[5,17,18] The International Olympic Committee has recommended 3D assessment of jump-landing mechanics as a gold standard method of analysis in the prevention of ACL injury.[19] Several prospective and retrospective studies have reported significant associations between 3D kinematic data of dynamic tasks and injury in the lower limb, particularly acute and chronic knee injury.[18,20–22] However, 3D kinematic analysis is time consuming, costly, and largely unavailable to most of the sporting population. The LESS has been proposed as an alternative, easier method to assess jump-landing technique.[6,23] Previous prospective injury studies have reported that the LESS had a significant strong association with injury.[6] Padua et al[6] reported a strong relationship between LESS scores and 3D kinematics during a landing task. Our results support previous reliability studies, highlighting that the LESS is a reliable alternative method of assessing jump-landing mechanics.[6,10,11] This strengthens the use of the LESS as a potential alternative when 3D kinematic assessment is not available.

For those undertaking interventions with the LESS, the SEM of approximately 1 reported in our study indicates that LESS scores improving by 1 point or less may be due to test–retest variations rather than discernible improvements in jump-landing mechanics.[9] Our results highlight that practitioners should be confident that changes in LESS scores of more than 1 would be due to improvements in landing performance. Furthermore, those without prior experience with the LESS should be confident that the standardized instructions and scoring are adequate to develop acceptable reliability using the LESS.

Conclusion

Our results demonstrate that the LESS is a reliable screening tool. This was the first study to demonstrate that the LESS is a reliable screen with practitioners, who have only used the standardized scoring criteria. Where "gold standard" 3D kinematic assessment is not available, those involved in the prevention and rehabilitation of injury could use the LESS as a reliable alternative for the assessment of jump-landing mechanics.

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