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The Ability of the Landing Error Scoring System to Detect Changes in Landing Mechanics: A Critically Appraised Topic

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Clinical Question: Is there evidence to suggest that the Landing Error Scoring System (LESS) is able to detect functional changes in landing mechanics in healthy individuals after participation in an injury prevention program (IPP)? **Clinical Bottom Line:** In a healthy, physically active population, there is strong evidence to support the use of the LESS as an outcome measure for changes in landing mechanics after the implementation of IPPs. Clinicians should consider the LESS as an evaluative tool for measuring the efficacy of IPPs in clinical practice.

Clinical Scenario

Lower extremity injuries account for 50% of musculoskeletal injuries[1] and are a major concern for physically active populations. Movement patterns that predispose physically active individuals to injury can be identified and modified to reduce injury risk.[2] Lower extremity injury prevention programs (IPPs) focus on neuromuscular education with the goal of correcting biomechanical risk factors that may lead to injury.[3] These programs often include strengthening, range of motion, agility, plyometric, and balance exercises.[3] Meta-analyses have reported that IPPs are effective at reducing lower extremity injury risk for youth athletes,[4] reducing the risk of sport injuries for a variety of physically active groups ranging from military recruits to high school basketball players,[5] and reducing anterior cruciate ligament (ACL) injuries in female athletes.[3] Injury risk assessment tools have been developed to identify individual injury risk and quantify functional biomechanical change as a result of participation in IPPs.[2,6] One assessment tool which has become popular in both research and clinical practice is the Landing Error Scoring System (LESS).[2,6,7] The LESS is a valid and reliable assessment tool used to assess functional landing mechanics.[2,8] The LESS may be able to detect functional changes in landing mechanics after participation in an IPP to demonstrate the effectiveness of these programs.

Focused Clinical Question

Is there evidence to suggest that the LESS is able to detect functional changes in landing mechanics in healthy individuals after participation in an IPP?

Search Strategy

A computerized search was completed in November 2016 (Figure 1). The search terms used were:

- **P**atient/Client group: healthy subjects
- **I**ntervention: intervention OR injury prevention
- **C**omparison: none
- **O**utcome: LESS

Sources of Evidence Searched

- Medline
- Academic Search Complete
- CINAHL Plus
- SportDiscus
- PubMed
- Additional resources were obtained via review of reference lists and hand searches.

The criteria for study selection were as follows.

Inclusion Criteria

- Limited to studies that compared pre- and post-intervention LESS scores
- Limited to studies that used a clearly described IPP comprised of more than one type of exercise
- Limited to Level I evidence
- Limited to the English language
- Limited to human subjects
- Limited to the last 10 years (2005–2016)

Exclusion Criteria

- Studies that used other jump-landing tasks as an outcome measure
- Studies that did not clearly describe the IPP[9] or used an IPP that consisted of one type of exercise[10]
- Studies that used a study design other than a randomized clinical trial (RCT)[11,12]
- Studies that only included participants who had improved LESS scores from a previous IPP intervention[13]

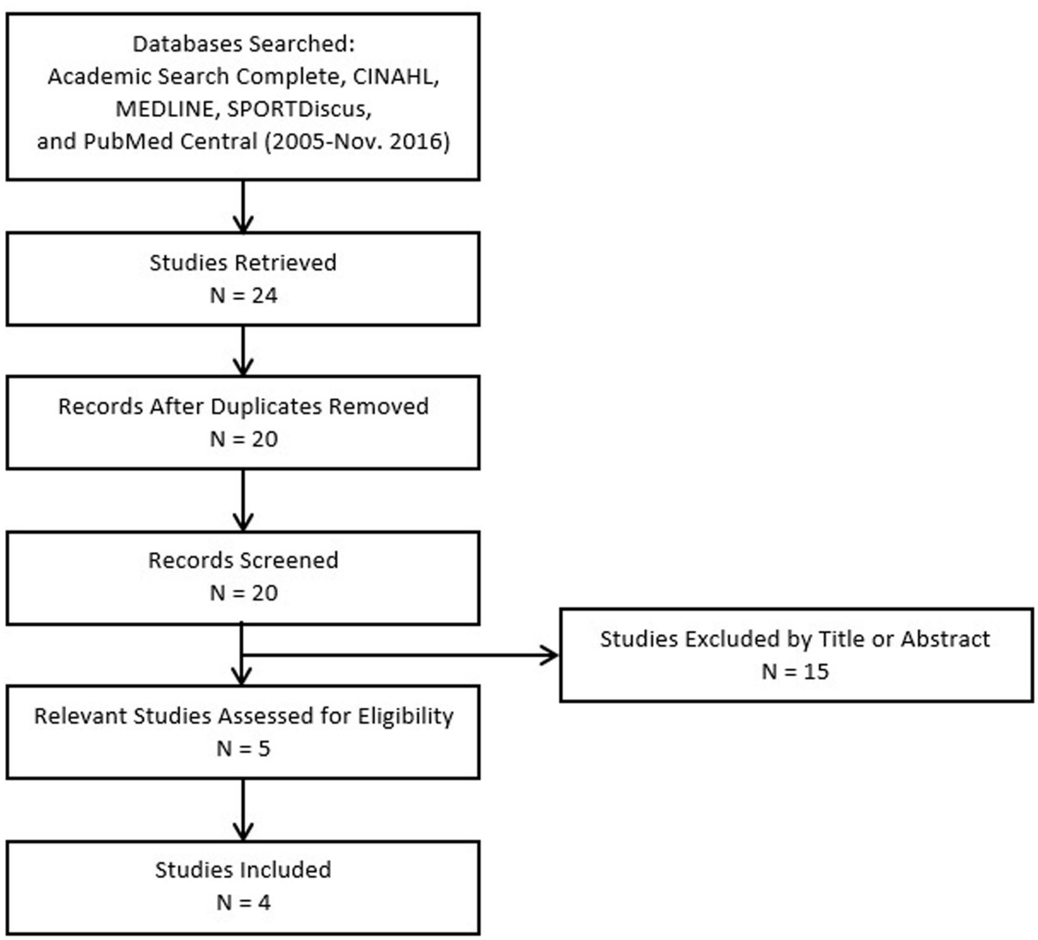

Figure 1 Summary of search.

Evidence Quality Assessment

Validity of the selected studies was determined using the Physiotherapy Evidence Database (PEDro) checklist for RCTs. The PEDro was selected by the four authors (CP, TR, EH, JH) as the acceptable appraisal instrument for the studies included in this Critically Appraised Topic (CAT) as each of the included studies was a RCT. All four authors met before appraisal to review the PEDro instrument and clarify the scoring criterion. Three authors (CP, TR, EH) independently reviewed the studies and completed the checklist. After appraisal, the three authors met and came to a consensus for each item on the checklist.

Results of Search

Summary of Search, Best Evidence Appraised, and Key Findings

- Four authors (CP, TR, EH, JH) searched the literature for studies of Level I evidence, based on the CEBM Levels of Evidence 1, that examined the LESS as an outcome measure for subjects who completed an IPP. All four authors met to determine study eligibility and inclusion in the CAT.
- Four[14–17] relevant studies were located (Table 1) that met the inclusion criteria and were included in this CAT. All studies included were Level I evidence.
- Each study examined the LESS scores pre- and post-completion of an IPP or a comparator program.
- All four included studies[14–17] demonstrated improvement in LESS scores from preintervention testing to postintervention testing. One study[15] demonstrated changes in LESS scores for both groups, while three studies[14,16,17] demonstrated changes for the IPP groups only.
- Root et al.[16] identified significant changes in LESS scores immediately following one IPP session. The authors also examined changes in other outcome measures such as the vertical jump, long jump, or shuttle run. No differences in these outcomes were identified.
- DiStefano et al.[14] demonstrated improvements in LESS scores utilizing an integrated IPP. In addition, participants improved in the T-test, sit-ups, and push-ups.
- One study[15] demonstrated participants in the IPP group had improvements in LESS scores that lasted for approximately 6 months.
- O'Malley et al.[17] demonstrated improvements in LESS scores after participating in the IPP. Improvements in Y-balance test reach directions and composite scores were also identified.

Results of Evidence Assessment

The four included studies were assessed using the PEDro scale. Two studies[14,16] scored a 9/10, one[15] received a 7/10, and one[17] received a 6/10. Two studies[14,16] did not directly address concealed allocation of randomized groups. In addition, two studies[15,17] failed to report proper blinding of either the subjects or the clinicians administering the intervention and groups were not similar at baseline. Finally, one study[17] did not obtain an outcome measure for more than 85% of the subjects initially allocated.

Clinical Bottom Line

In a healthy, physically active population, there is strong evidence to support the use of the LESS as an outcome measure for changes in landing mechanics after the implementation of IPPs. Clinicians should consider the LESS as an evaluative tool for measuring the efficacy of IPPs in clinical practice.

Strength of Recommendation

Based on the CEBM Levels of Evidence 1,[18] there is grade B evidence that the LESS is an effective tool for detecting changes in landing mechanics after the implementation of an IPP. According to the CEBM Levels of Evidence 1, grade B is reserved for consistent Level 2 and 3 evidence or extrapolated Level 1 evidence.[18] Although demonstrating high scores on the PEDro, a grade of B was recommended due to the variation of IPPs used in the included studies.

Implications for Practice, Education, and Future Research

The studies in this CAT examined the LESS as an outcome measure for detecting changes in landing mechanics after the implementation of an IPP.[14–17]

Table 1 Characteristics of Included Studies

Study Authors	Distefano, Marshall, et al.[15]	DiStefano, DiStefano, et al.[14]	O'Malley et al.[17]	Root et al.[16]
Study Title	The Effects of an Injury Prevention Program on Landing Biomechanics Over Time	Comparison of Integrated and Isolated Training on Performance Measures and Neuromuscular Control	The Effects of the GAA15 Training Program on Neuromuscular Outcomes in Gaelic Football and Hurling Players: A Randomized Cluster Trial	Landing Technique and Performance in Youth Athletes After a Single Injury-Prevention Program Session
Study Participants	1,104 physically active students (928 males, 176 females), ages 17–22	30 physically active students (25 males, 5 females), ages 19–21	78 18-year-old males who participated on hurling or football teams	89 active children (60 boys, 29 girls), ages 13 ± 2 years
Inclusion/ Exclusion Criteria	Inclusion: Incoming freshman to the academy, free from injury or illness that prohibited physical activity at the time of testing	Inclusion: Students enrolled in an introductory weight training class, free of injury or illness that prohibited physical activity at the time of testing	Inclusion: Male athletes over 18, no current injury, on a team that trained 2 or more times per week	Inclusion: Member of a fall or winter team sport (soccer, dodgeball, cross-country, football, basketball) at a local junior boarding school in grades 5–9. Exclusion: Self-reported injury or illness that prevented physical activity

(continued)

TABLE 1 *(continued)*

Study Authors	Distefano, Marshall, et al.[15]	DiStefano, DiStefano, et al.[14]	O'Malley et al.[17]	Root et al.[16]
Intervention	All participants were randomized to either the standard warm-up group (SWU) or the dynamic integrated movement enhancement group (DIME). BOTH: 10–12 min warm-up plan consisting of dynamic flexibility, strengthening, agility, and plyometric exercises. DIME: Extra concentration on balance and proper alignment during movements; double leg squat, squat jump, forward lunge, side plank, push-up, single-leg reach, side hop to balance, ice skater, L hop. SWU = 10 standard exercises used in US army pretraining; bend and reach, rear lunge, high jumper, rower, squat bender, windmill, forward lunge, prone row, bent-leg body twist, push-up.	Participants were cluster randomized by class to either an isolated (ISO) or integrated (INT) training program. Both groups participated in a 2-times-per-week for 8-weeks integrated training program that lasted 45 min. Both groups did a standardized warm-up of a 10-min bike ride and static stretching of the calves, groin, hip flexors, low back, and chest muscles. The cool-down was also the same where the participants repeated of the static stretches done during the warm-up. ISO program participants completed a total of 5 upper- and lower-body resistance exercises for the first 4 weeks and progressed to 10 exercises in the last 4 weeks. The exercises' resistance progressed throughout the 4 weeks. INT program participants performed exercises aimed on improving core stability, power, agility, and strength. The exercises progressed in difficulty throughout the 8 weeks. Intensity of the program increased by adding repetitions, resistance, and exercise modifications.	Participants were cluster randomized by team to the intervention group (GAA 15) or control group (CON). CON: The teams were instructed to continue with their normal training programs. GAA 15: The program was 15 min in duration and was completed at the beginning of the training session 2 times per week for 8 weeks, for a total of 16 training sessions. The exercises in the GAA 15 training program focused on strength, core-stability, balance, movement control, plyometric, and agility. The exercises were progressed throughout participation in the training program. Level I exercises were performed weeks 1 and 2, Level II exercises were performed weeks 3–5, and Level III exercises were performed weeks 5–8.	Participants were randomized into 3 groups. Each warm-up lasted 10–12 min. Static warm-up (SWU): 5-min jog followed by bilateral stretches for hamstrings, quadriceps, gastrocnemius and soleus complex, hip flexors, and hip adductors. Each stretch was held for 30 s. Dynamic warm-up (DWU): Focusing on gradual increase in intensity, this group performed 10 min of dynamic stretching (hamstrings, quadriceps, gastrocnemius and soleus complex, hip flexors, hip adductors, and gluteal muscle groups) and agility exercises, 10-min acceleration run, and recovery jog. Injury-prevention program (IPP): This group also employed a gradual increase in intensity beginning with 10 min of dynamic stretching (hamstrings, quadriceps, gastrocnemius and soleus complex, hip flexors, hip adductors, and gluteal muscle groups) and agility exercises, 10-min acceleration run, and recovery jog. In addition, this group performed balance and plyometric exercises.

(continued)

Table 1 *(continued)*

Study Authors	Distefano, Marshall, et al.[15]	DiStefano, DiStefano, et al.[14]	O'Malley et al.[17]	Root et al.[16]
Outcome Measures	All measurements were assessed immediately before intervention (PRE), immediately after intervention (POST), and then 2 (POST2M), 4 (POST4M), 6 (POST6M), and 8 (POST8M) months after the intervention. All outcomes were collected PRE and POST; only 400 were graded. 150 participants were tested and assessed at each of the POST2M–POST8M months. Outcomes: Digital video recording of the Landing Error Scoring System (LESS), vertical ground reaction forces, and lower extremity injury occurrence.	All measures were collected 1 week before program implementation (PRE) and 1 week after cessation (POST). Outcomes: Landing Error Scoring System (LESS), sit-and-reach test, T-test, vertical jump test, sit-up assessment, and push-up assessment.	All measures were assessed 1 week before program implementation (PRE) and after the intervention session (POST). Outcomes: The Landing Error Scoring System (LESS) and the Y-balance test. Participants were classified according to LESS score as follows: excellent (≤ 4), good (5), moderate (6), and poor (> 6).	All measures were assessed preintervention (PRE) and 10-min postintervention (POST) for the following outcomes in a single 30–45 min testing session. Outcomes: Landing Error Scoring System (LESS); maximum vertical jump height; standing long jump (maximum distance achieved in a single jump); shuttle run time (time to complete 2 repetitions of a 30-m down-and back sprint).
Results	There were no group differences in LESS change scores at any time point. Both groups improved their LESS scores at POST, POST4M, and POST6M compared with the PRE measure; SWU group also improved at POST2M compared with PRE.	There was a significant interaction for the LESS scores, T-test, sit-ups, and push-ups. The INT group improved LESS scores, T-test time, and reps on the sit-ups and push-ups at POST when compared with the PRE and when INT POST was compared with POST ISO. The ISO group did not show improvement in LESS scores. Both the INT and ISO group performed more push-ups, jumped higher, and reached farther at POST.	The LESS POST scores were significantly different in the GAA 15 group than the CON group. The GAA 15 PRE LESS classification was poor and improved to excellent POST. The CON group PRE LESS was poor and remained POOR at POST.	There was a significant difference between groups for the LESS change score; the IPP group had greater improvement than the SWU and DWU groups.
Level of Evidence	7/10	9/10	6/10	9/10
Support for the Answer	Yes. LESS scores improved after either intervention program, but results dissipated after 6 months of the intervention.	Yes. LESS scores improved at POST for the INT group.	Yes. LESS scores improved at the POST for the GAA 15 group compared with controls.	Yes. The LESS scores showed a statistically significant improvement for only the IPP group.

The LESS is a clinical assessment tool used to quantify the risk of lower extremity injury by examining an individual's jump-landing biomechanics. Research has suggested the LESS is a valid measure for examining jump-landing biomechanics and has good interrater reliability (intraclass correlation coefficient [ICC] = 0.84) and excellent intrarater reliability (ICC = 0.91).[2,7] To complete the LESS, individuals are instructed to jump from a 30-cm box to a distance of half of their height away from the box and immediately rebound for a maximal vertical jump upon landing.[2] Subjects are typically given two practice trials and three test trials. Successful jumps are characterized by: (1) jumping off with both feet, (2) jumping forward from the box, (3) landing with both feet simultaneously, (4) jumping for height upon landing, (5) completing the task in a fluid sequence.[2] Cameras are placed anteriorly and laterally to capture both frontal and sagittal views of the jump landing task.[2,14,16] The LESS is scored on 17 criteria: items 1–6 evaluate lower extremity and trunk position at the point of initial contact with the ground and are assessed in both the sagittal (1–4) and frontal view (5–6). Items 7–11 evaluate stance and foot placement in the frontal plane at various points during the jump landing task.[3] Items 12–14 evaluate knee, hip, and trunk flexion in the frontal view, while item 15 assesses knee valgus displacement in the sagittal view.[3] Finally, item 16 assesses overall joint displacement in the sagittal plane while item 17 is an overall impression of the landing.[3] The final LESS score is calculated by totaling the number of "errors" observed by the clinician. A higher LESS score indicates a greater number of errors committed during the landing, which may correspond to movements that carry higher risk of injury.[2]

Minimum detectable change (MDC) is the amount of change necessary to be considered change that is not due to measurement error. This measure is important when examining whether changes over time are clinically meaningful. The MDC was calculated using the following equation: $SEM * \sqrt{2} * 1.96$.[19] Using an *SEM* of 0.42 and ICC = 0.91,[2] the intrarater MDC for LESS is 1.16. Therefore, clinicians need to observe a decrease in one or more biomechanical errors to observe change outside of measurement error. O'Malley et al.[17] used a "warm-up" style program and found an adjusted mean change in LESS scores of 2.5 in the IPP group, which exceeded the calculated MDC. For DiStefano, Marshall, et al.,[15] the only change in LESS scores that exceeded the MDC was the premeasure versus the post-6-month measure. None of the LESS scores examined by Root et al.[16] exceeded the MDC. The actual LESS data were not reported in the DiStefano, DiStefano, et al.[14] article.

An additional variable to consider when deciding if the amount of change in LESS scores after participation in an IPP is clinically meaningful is whether there was a reduction in injury risk. A cutoff score of 5 has been calculated for the LESS, indicating individuals who score less than five errors are at a reduced risk for injury than those who score greater than five errors.[6] O'Malley et al.[17] found an improved LESS score of 4.1 after participation in a "warm-up "style program, which indicates the participants were at a decreased risk for injury. Root et al.[16] was able to improve the number of errors on the LESS postintervention; however, the average score remained above the cutoff score, which indicates participants remained at an increased risk of injury. The two additional articles[14,15] in this CAT did not provide enough information to determine if their scores improved below the cutoff scores. Therefore, while most of the studies included in this CAT identified significant changes in LESS scores after the implementation of an IPP, the clinical meaningfulness of the changes must be examined.[15]

There are numerous IPPs that have been studied extensively in the literature. The four studies[14–17] included in this CAT used six distinctive IPPs. Two[16,17] were classified as "warm-up" style programs involving 10–15 min of activity before sport, while the others were unrelated to specific sport activity and ranged from 10 to 45 min of intervention exercises. These IPPs included varying amounts of stretching,[14–16] strengthening,[14–17] balance,[14–17] plyometric and landing exercises,[14–17] agility,[14–17] core stability,[14,15,17] cardiovascular conditioning,[14,16] targeted interventions based on pretest movement patterns,[15] and participant education.[16] Given that the IPPs used in these studies included the aforementioned exercises such as landing exercises, education, and core strengthening, it is understandable that changes in LESS scores were identified for all participants. However, in addition to whether LESS scores were reduced, validity of these IPPs to reduce lower extremity injuries must also be examined. DiStefano, Marshall, et al.[15] were the only investigators to track lower extremity injuries over time. While each group sustained lower extremity injuries, there was no difference in injury rates between the two groups.[15] However, the risk of sustaining an injury was lower 2–4 months after participants completed the intervention compared with 6–8 months postintervention.[15]

Although this CAT focused specifically on the LESS, the articles included examined other outcome measures. These measures included vertical jump height,[14,16] long jump for distance,[16] shuttle run,[16] sit and reach,[14] T-test run,[14] sit-up assessment,[14] push-up assessment,[14] peak vertical ground reaction force,[15] dynamic balance,[17] and injury incidence rate.[15] Of these measures, significant differences between time points were identified for the vertical ground reaction forces,[15] push-up assessment,[14] vertical jump height,[14] T-test run for agility,[14] dynamic balance,[17] and sit and reach for flexibility test.[14] These results indicate other outcome assessments may be effective in the identification of functional change post-IPP intervention; however, recommendations regarding these assessment measures are beyond the scope of this CAT.

The purpose of this CAT was to determine the ability of the LESS to detect changes in landing biomechanics in healthy individuals who participated in an IPP. The search results revealed four studies[14–17] that met our inclusion criteria, and all four studies[14–17] reported changes in LESS scores after participants completed an IPP. Of further interest is that one study[16] identified improvements in LESS scores immediately after one IPP session and another study identified improvements in LESS scores 6 months after program cessation.[15] While some studies examined duration of IPP and follow-up time, future research should continue to investigate the duration of IPP participation needed to identify changes in landing mechanics and the retention of biomechanical changes in these healthy populations. Additional research should include focused educational interventions and include a measure of compliance with the IPPs. Future research should continue to investigate whether improving LESS scores actually reduces the risk of lower extremity injury. Future research should continue to investigate the clinical utility of the LESS-Real Time7 as an outcome measure for IPPS. While all of the included studies demonstrated improvements in LESS scores after IPP participation, not all studies demonstrated clinically meaningful improvements in scores or reduced LESS scores below the previously established cutoff score. However, we believe the evidence presented in this CAT supports the use of the LESS pre- and post-IPP to determine efficacy of an IPP and to objectify change in injury risk for an individual regardless of the type of IPP. This CAT should be reviewed in 2 years (2018) to determine whether there is additional best evidence that may change the clinical bottom line for this clinical question. ■

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