CLINICAL IMPLICATIONS OF LANDING ERROR SCORING SYSTEM CALCULATION METHODS

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Abstract

Objectives: To explore whether final Landing Error Scoring System (LESS) scores differ between calculation methods used in literature.

Design: Cross-sectional.

Setting: Laboratory.

Participants: 328 individuals.

Main outcome measures: LESS scores from 984 drop-jumps were extracted. Final LESS scores were calculated for every participant according to five methods: mean of 3 jumps, 1st jump score, 3rd jump score, best jump score, and sum of errors present in at least 2 jumps. The influence of the calculation method on group mean LESS score and group-level risk categorization using threshold of 5 errors was estimated using Generalized Estimating Equations, with the mean of 3 jumps score set as the reference method. The agreement in individual-level risk categorization was assessed using odds ratios and McNemar's tests.

Results: Compared to the reference, estimated group mean LESS score was 0.92 errors lower ($p <$ 0.001) using the best jump method, as was group-level risk categorization (odds ratio: 0.50, $p <$

0.001). Individual-level risk categorization between calculation methods was inconsistent for 8 to 15% of participants compared to the reference method, significantly different from reference for the best jump score method ($p < 0.001$).

Conclusions: Calculation method meaningfully influences final LESS scores and risk categorization.

Highlights:

- Best jump method provided meaningfully different LESS scores than reference method.
- Comparing studies using different computation methods should be done with caution.
- Using consistent LESS protocol and final score computation method is recommended.
- Research needs to state computation methods clearly for valid inferences.

Keywords

injury risk, jump-landing biomechanics, movement screen

Introduction

The Landing Error Scoring System (LESS) is a clinical-based screening tool developed by Padua et al., (2009) used to identify individuals at risk of suffering a non-contact anterior cruciate ligament (ACL) injury through the evaluation of potentially high-risk biomechanical movement patterns. The LESS relies on the use of two standard video cameras to capture motion in the frontal and sagittal planes during three trials of a double-leg vertical drop-jump (VDJ) task. When compared to three-dimensional motion capture systems, which is considered the "gold standard" tool for quantifying human movement, standard two-dimensional video cameras require considerably less financial outlay as well as preparatory time and space to perform the analysis. Therefore, the LESS is more practical for large-scale screening initiatives. To score the LESS, an investigator visually evaluates lower-extremity and trunk kinematics during landing from the video recordings, noting the number of 'movement errors' using a 17-item scoring sheet (Padua et al., 2009). LESS scores range from 0 to 17 errors, where higher scores indicate a greater number of landing errors.

The LESS has been shown to be a reliable screening tool (Hanzlíková & Hébert-Losier 2019). Although the validity of the LESS against three-dimensional motion capture data has been shown to be strictly item dependent; the items representing the key risk factors for ACL injury were shown to be valid (Hanzlíková & Hébert-Losier 2019). Padua et al., (2015) evaluated ACL risk in elite-youth soccer players in a prospective study and concluded that LESS scoring exhibited good sensitivity (86%) and acceptable specificity (64%) to identify risk of non-contact ACL injury, ascertaining 5 errors as the threshold for high injury risk. More specifically, the relative risk of sustaining an ACL injury was 10.7 times greater in individuals with a LESS score of 5 or more (high risk) compared to less than 5 (low risk). In contrast, Smith et al., (2012) did not find any significant relationship between LESS and ACL injury incidence. Differences in sampled populations in terms of age, main sporting event, and previous injury status, as well as lack of statistical power in both studies (Padua et al., 2015; Smith et al., 2012), are potential underlying factors to the diverging findings on the predictive value of the LESS.

Padua et al., (2009) provided operational definitions and scoring details for each item of the LESS on conception, but the authors did not explicitly specify how to compute the final LESS score from the 3 recommended VDJ trials (e.g., whether to use the mean or the best trial). In the footnotes of online Appendix that presented how frequent positive scores were in their population, Padua et al., (2009) stated: "For items 1 to 15, a positive score was defined as an error on at least 2 of the 3 trials. For item 16 and 17, a positive score was defined as Average on at least 2 of 3 trials or Poor/Stiff on at least 1 of 3 trials." These footnotes infer that final LESS scores derived from items where errors were present in at least 2 of 3 trials, but this computational approach was never clearly stated in the methods. Furthermore, in subsequent articles from the same group of authors, the mean score of 3 VDJ trials was used to allocate the final LESS score to individuals (Padua et al., 2015; Padua et al., 2012).

In scientific literature, most studies using the LESS as an outcome measure calculate the final LESS score for an individual as a mean of 3 VDJ trials (Beese, Joy, Switzler, & Hicks-Little 2015; Beutler, de la Motte, Marshall, Padua, & Boden 2009; DiStefano et al., 2018; DiStefano, Padua, DiStefano, & Marshall 2009; Kuenze, Foot, Saliba, & Hart 2015; Mohammadi, Shojaadin, Letafatkar, Ebrahimi, & Eslami 2017; Padua et al., 2015; Padua et al., 2012; Pfile, Gribble, Buskirk, Meserth, & Pietrosimone 2016; Scarneo et al., 2017; Smith et al., 2012; Theiss et al., 2014; Welling, Benjaminse, Gokeler, & Otten 2016; Wesley, Aronson, & Docherty 2015), although some studies have used the LESS score of the 1st jump (Onate, Cortes, Welch, & Van

Lunen 2010), 3rd jump (O'Malley, Murphy, Persson, Gissane, & Blake 2017), or best jump (Garbenytė-Apolinskienė, Šiupšinskas, Salatkaitė, Gudas, & Radvila 2017; Kraus, Schutz, & Doyscher 2017) for analysis. Additionally, two studies scored an error if the participant demonstrated the specific error in at least 2 of the 3 VDJ trials (Bell, Smith, Pennuto, Stiffler, & Olson 2014; Pryor et al., 2017). Only a few authors justified their selected calculation methods: Onate et al., (2010) scored the 1st jump only to reduce possible biases between the two raters scoring each participant; whereas Bell et al., (2014) and Pryor et al., (2017) selected the sum of errors present in at least 2 jumps method to analyse the frequency of individual LESS item errors. There is a lack of knowledge on the effect of computational method on the final LESS score and risk categorization of individuals.

It is essential in both research and practice that outcomes from assessments are reproducible and comparable between studies to improve healthcare management and scientific inference. Therefore, our aim was to explore whether final LESS scores significantly differ between calculation methods used in the scientific literature. We hypothesized that the calculation method would significantly influence the estimated group mean LESS score, group-level risk categorization, and individual-level risk categorization, anticipating lower scores and lesser individuals categorized at high risk using the LESS score from the best trial versus the mean of 3 VDJ trials. On the other hand, we expected similar scores between methods based on the mean score from 3 VDJ trials and sum of errors present in at least 2 trials.

Methods

Power analysis

The sample size calculation for this study was based on data from the two methods we assumed would demonstrate the smallest mean difference; (i.e., mean of 3 jumps (Root, Trojian, Martinez, Kraemer, & DiStefano 2015) and sum of errors present in at least 2 jumps (Pryor et al., 2017)). Sample size requirements were calculated using a customizable statistical spreadsheet (Hopkins 2006) from standard two-tailed hypothesis equations using an 90% power (β = 0.10), 5% significance level (α = 0.05), critical values of the *t* distribution, and data from previous studies (Pryor et al., 2017; Root et al., 2015) on similar cohorts (i.e., healthy young individuals). These equations indicated that we needed 273 participants to identify group differences in mean LESS scores between these two calculation methods. To account for 20% of potential withdrawals and missing data, we recruited 328 participants.

Participants

A sample of 328 participants (167 males and 159 females) volunteered to participate. Age, height, mass, and body mass index (mean ± standard deviation) for males were 18.3 ± 4.0 years (range 15 to 42 years), 180.9 ± 7.9 cm, 86.7 ± 16.4 kg, and 26.5 ± 4.7 kg/m^2; and for females were 17.8 ± 4.6 years (range 12 to 41 years), 168.9 ± 6.2 cm, 67.9 ± 12.1 kg, and 23.8 ± 4.0 kg/m^2. All participants were involved in physical activity: On average 3 times per week, 6 hours a week. The majority of participants (90%) participated in team sports (53% rugby, 21% netball, 7% soccer, 5% field hockey, and 4% other team sports). Participants had to be free from injury, pain, or any other issue limiting physical activity participation at the time of study participation. Previous injuries were not an exclusion criterion. The study protocol was approved by our Human Research Ethics Committee [HREC(Health)#41] and adhered to the Declaration of Helsinki. All participants and their legal guardian when younger than 16 years of age signed a written informed consent document that explained the potential risks associated with testing.

Testing procedure

The testing procedure we used was identical to that described by the developers of the LESS (Padua et al., 2009). For the VDJ, we asked participants to jump horizontally from a 30-cm high box to a line placed at 50% of their body height, and immediately rebound for a maximal vertical height. The successful trial was defined as jumping off the box with both feet, landing in front of the designated line, jumping as high as possible straight up in the air upon landing from the box, and completing the task in a fluid motion. We did not provide any feedback on participants landing technique unless they were performing the task incorrectly. Participants used their own sport footwear for testing.

After providing instructions and allowing practice jumps for familiarization (typically 1), each participant performed three successful trials of VDJ in front of two standard video cameras capturing at 120 Hz (Sony RX10 II, Sony Corporation, Tokyo, Japan) with an actual focal length of 8.8 to 73.3 mm (35-mm equivalent focal length of 24-200 mm). We mounted the cameras on tripods placed 3.5 m in front of and to the right side of the landing area with a lens-to-floor distance of 1.3 m. We allowed participants to rest until they felt ready to perform the task again to limit fatigue. The total testing time was typically 2 minutes per participant.

A qualified physiotherapist who completed over 400 LESS evaluations prior to this study replayed the videos using the Kinovea software (version 0.8.15, www.kinovea.org) and scored all trials using the 17-item LESS scoring sheet (Padua et al., 2009). The physiotherapist used the video analysis software as proposed as a mean to improve the psychometric properties of the LESS (Onate et al., 2010). The average scoring time was typically 4 minutes per one VDJ. The final LESS score was calculated for every participant according to the five methods reported in the scientific literature: 1) mean of 3 jumps, 2) 1st jump score, 3) 3rd jump score, 4) best jump score, and 5) sum of errors present in at least 2 jumps. The overall LESS score demonstrates good-to-excellent intra-rater (ICC = 0.82 to 0.99) and inter-rater (ICC = 0.83 to 0.92) (Hanzlíková & Hébert-Losier 2019)

Statistical method

From our data, we assessed the effect of calculation method on: 1) estimated group mean LESS score, 2) group-level risk categorization [proportion of participants categorize at high (LESS ≥ 5) and low (LESS < 5) injury risk], and 3) individual-level risk categorization (consistency of high and low injury risk category and odds of being at high risk for individual participants). The mean of 3 jumps method is the most common (Beese et al., 2015; Beutler et al., 2009; DiStefano et al., 2018; DiStefano et al., 2009; Kuenze et al., 2015; Mohammadi et al., 2017; Padua et al., 2015; Padua et al., 2012; Pfile et al., 2016; Scarneo et al., 2017; Smith et al., 2012; Theiss et al., 2014; Welling et al., 2016; Wesley et al., 2015); therefore, we set the mean of 3 jumps as the reference method in all analyses and compared other methods to the reference method. Note that comparisons between all methods are presented in Appendix A−D.

The influence of the calculation method on group mean LESS score and group-level risk categorization was estimated using a Generalized Estimating Equation (GEE) (Liang & Zeger 1986). We selected the GEE approach as estimates consider the variation within individuals in presence of multiple observations. The GEE approach provides an estimate with its 95% confidence interval [lower, upper] of the average effect in a population, applying robust standard errors to account for within-individual correlations.

We used the GEE model with a Gaussian (normal) distribution to explore the influence of the final LESS score calculation method on the group mean LESS score. It is common in studies using a single trial for the final LESS score calculation to report LESS scores as continuous data (i.e., mean and standard deviation) (Garbenytė-Apolinskienė et al., 2017; Kraus et al., 2017; O'Malley et al., 2017) despite the data being ordinal in nature. This approach is fundamentally flawed; however, to be able to compare group mean LESS scores between different calculation methods, we made the assumption that the continuous outcome of the reference method (mean of three jumps) was comparable to the ordinal outcomes of the other methods. We used a GEE model with a binominal distribution to explore the influence of calculation method on group-level risk categorization, estimating the odds ratio of being at high risk of injury for a given method compared to the reference method. Both GEE models applied an exchangeable correlation structure, which assumes that all observations have the same amount of correlation over time. To have more certainty that differences between methods were not due to multiple comparisons, we decided a priori to adjust the 95% confidence intervals and *p*-values using the Bonferroni method in post-hoc analysis.

To explore the individual-level risk categorization, we assessed the agreement (*n* and %) in risk categorization with regards to the reference method using odds ratio and McNemar's tests. The odds ratio shows which one of the two methods is more likely to score individuals at high injury risk; i.e., the number of participants at high risk exclusively for a given method divided by the number of participants at high risk exclusively for the reference method. McNemar's test compares two proportions; in our case, whether the proportion of participants at high injury risk for a particular calculation method significantly differs from that of the reference method.

We set a significance level of $p \leq 0.05$ for all analysis. The statistics were computed using Microsoft® Excel for Office 365 MSO and RStudio® version 1.1.463 with R version 3.5.2. All participants finished the study and we analyzed the complete data set.

Results

The group mean ± standard deviation (minimum to maximum) LESS score was: 6.07 ± 1.71 errors (0.67 to 11.67 errors) for the reference method; 5.87 ± 1.87 errors (0 to 11 errors) for the 1st jump method; 6.10 ± 2.00 errors (1 to 13 errors) for 3rd jump method; 5.13 ± 1.75 errors (0 to 11 errors) for best jump score method; and 6.02 ±1.90 errors (1 to 13 errors) for sum of errors present in at least 2 jumps method.

Estimated group mean LESS score

From our data, the GEE model estimated a group mean LESS score of 5.91 [5.73 to 6.10] errors for the reference method. The GEE group mean LESS score estimated from the best jump method was significantly lower than the reference method ($p < 0.001$; Table 1). Comparisons of estimated group mean LESS scores between all methods are presented in Appendix A and B.

Table 1. Comparison of the group mean Landing Error Scoring System score between other methods versus reference method using Generalized Estimating Equations.

Method	Mean difference in LESS scores* (error) [95% CI]	*p* – value*
1st jump score	-0.16 [-0.55 to 0.24]	1.000
3rd jump score	0.07 [-0.34 to 0.48]	1.000
Best jump score	-0.92 [-1.30 to -0.54]	< 0.001
Error present in at least 2 jumps	-0.01 [-0.41 to 0.38]	1.000

Mean of 3 jumps was set as the reference method. Abbreviations: LESS, Landing Error Scoring System; CI, confidence interval. * difference versus reference method using the Bonferroni correction.

Group-level risk categorization

Table 2 presents the number of individuals categorized at high and low risk of injury for each method. At a group-level, odds of high-risk categorization was significantly lower in the best jump score method compared to the reference method based on GEE analyses (odds ratio 0.50, $p < 0.001$, Table 2). Comparisons of odds ratios between all methods are presented in Appendix C and D.

Table 2. Number of participants at high and low risk and Generalized Estimating Equation of the group-level risk categorization.

Method	**Participants at high risk**	**Participants at low risk**	**Odds ratio* [95% CI]**	***p* – value***
Reference method	76% (*n* = 249)	24% (*n* = 79)	--	--
1st jump score	77% (*n* = 251)	23% (*n* = 77)	1.03 [0.75 to 1.43]	1.00
3rd jump score	80% (*n* = 261)	20% (*n* = 67)	1.24 [0.90 to 1.69]	0.569
Best jump score	61% (*n* = 201)	39% (*n* = 127)	0.50 [0.39 to 0.65]	< 0.001
Error present in at least 2 jumps	79% (*n* = 260)	21% (*n* = 68)	1.21 [0.94 to 1.57]	0.333

Mean of 3 jumps was set as a reference method. Abbreviations: CI, confidence interval. Odds ration greater than 1.00 indicate higher odds of high injury risk category for given method compared to the reference method. *comparing other methods with reference method using the Bonferroni correction.

Individual-level risk categorization

At an individual level, inconsistency in risk categorization compared to the reference method ranged from 8 to 15% across methods (Table 3). The individual-level risk categorization was significantly different for the best jump score compared to the reference method ($p < 0.001$, Table 3), with a greater number of individuals exclusively at high risk for the reference method.

Table 3. Individual-level risk categorization. Four calculation methods are compared to the reference method (mean of 3 jumps).

Method	Consistent[a]	Inconsistent[a]	High risk given method[b]	High risk reference method[b]	Odds ratio[c] [95% CI]	McNemar's test *p* – value*
1st jump score	85% (*n* = 280)	15% (*n* = 48)	*n* = 25	*n* = 23	1.09 [0.62 to 1.92]	0.885
3rd jump score	88% (*n* = 288)	12% (*n* = 40)	*n* = 26	*n* = 14	1.86 [0.97 to 3.56]	0.081
Best jump score	85% (*n* = 280)	15% (*n* = 48)	*n* = 0	*n* = 48	--	< 0.001
Error present in at least 2 jumps	92% (*n* = 301)	8% (*n* = 27)	*n* = 19	*n* = 8	2.38 [1.04 to 5.43]	0.052

Abbreviations: CI, confidence interval. **p*-value: difference in individual-level risk categorization versus reference method.

[a] Participants categorized consistently/inconsistently versus the reference method.

[b] Participants categorized at high risk exclusively for a given/reference method.

[c] The number of participants at high risk exclusively for a given method divided by the number of participants at high risk exclusively for the reference method.

Discussion

The use of clinical tools such as the Landing Error Scoring System (LESS) to assess injury risk is common in sport science and clinical practice (Dallinga, Benjaminse, & Lemmink 2012; McCall et al., 2015). It is essential that clinical tools provide outcomes that are reproducible and comparable between practitioners and studies to improve healthcare management and scientific inference. The authors who introduced the LESS to the scientific community did not explicitly specify the method used to calculate the final LESS score (Padua et al., 2009). As a result, five different calculation methods have been reported in the literature. This paper explored the influence of these five calculation methods on estimated group mean LESS scores, group-level risk categorization, and individual-level risk categorization. We provide clinically meaningful evidence that the LESS calculation method can affect clinical outcomes and their interpretation and result in altering injury risk classification of participants and affecting injury prevention efforts.

LESS data are commonly averaged and compared between (e.g., males versus females, injured versus uninjured) or within (e.g., pre versus post intervention) groups to make clinical inferences (DiStefano et al., 2018; Pryor et al., 2017; Smith et al., 2012). When we compared estimated group mean LESS scores using different calculation methods, we found that the best jump method led to lower LESS score estimates (0.92 errors, $p < 0.001$) compared to the reference method. According to a literature review exploring the psychometric properties of the LESS (Hanzlíková & Hébert-Losier 2019), the standard error of measurement (SEM) for intra-rater reliability is 0.19 to 0.52, inter-rater reliability is 0.71, and test-retest reliability is 0.81. These SEM values indicate that the magnitude of the difference in estimated group mean LESS score between the best jump and reference calculation methods is clinically meaningful. According to Padua et al., (2009), poor LESS scores are associated with decreased peak knee and hip flexion angles, and increased peak knee valgus angles and moments, all of which have been associated with high injury risk landing strategies (Hewett et al., 2005). Basing the final LESS score of individuals on their best jump (i.e., the trial with the lowest number of errors) may mask their innate risk of injury and habitual movement patterns. The greatest similarity with the reference method was the 3rd jump score and score with an error present in at least 2 jumps. To score only the 3rd jump rather than all three jumps could be beneficial for large scale screening initiatives, as it would decrease the total scoring time and associated costs, yet still reflect typical group-level performance according to our analyses.

On the other hand, when the group-level risk categorization (number of participants at high and low injury risk) is of interest, the odds of being categorized at high risk of injury was significantly lower using the best jump score method compared to the reference one (odds ratio 0.50, $p < 0.001$). This significant difference in risk classification between methods could lead to different interpretations of clinical and research outcomes. The 1st jump score calculation method was the most comparable to the reference method in terms of risk categorization at a group-level (odds ratio 1.03). The 1st jump score method could be suitable for use when the proportion of participants at high and low injury risk is of interest, and when the time available for testing and scoring is limited as it only requires completing of a single VDJ instead of three. Although not as similar in magnitude to the reference method in terms of group mean LESS scores compared to the 3rd jump score method (see Table 2), using the 1st jump score might offer the best compromise in terms of reflecting LESS data from three trials and risk categorization at a group level.

Previous literature reviews and meta-analyses provide evidence for the effectiveness of neuromuscular training programs in reducing the incidence of sport injuries (Hübscher et al., 2010; Yoo et al., 2010), including ACL. For injury prevention programs to be cost-effective and efficient, identifying individuals at high injury risk is important. In individual-level risk categorization, the method most consistent (92%) with the reference method was that of scoring errors present in at least 2 jumps, although participants were more likely to be categorized at high risk of injury exclusively for this method (19 participants) compared to exclusively for the reference method (8 participants). The advantage of the errors present in at least 2 jumps method is that it reflects the typical errors of an individual. Practitioners can use this information to target these faulty movement patterns in individual preventative programs. The other calculation methods had a 12 to 15% inconsistency in risk categorization compared to the reference method, reaching statistical significance for the best jump score method ($p < 0.001$). The odds ratio for the best jump score compared to the reference method is infinity, as the best jump score (jump with the lowest number of errors) will always have a similar or lower number of participants at risk when compared to the reference method (mean of 3 jumps).

Scoring a single trial may sometimes be needed when resources (time or finance) are constrained or to answer a specific question, such as to determine the best possible performance of a person. However, it is important to note limitations in the use of a single trial to encapsulate an individual's movement patterns. Given that variability is present in all human movement, using a single trial may result in a poor representation of an individual's inherent movement variability. More specifically, a single trial protocol may by chance represent a typical performance, but also an atypical one. Using a single trial has been proposed invalid and unreliable for testing human movement (Bates, Dufek, & Davis 1992). Previous studies have concluded that averaging a minimum of four trials is needed to achieve stability in ground reaction force variables during double-leg landing (James, Herman, Dufek, & Bates 2007); eight to thirteen trials for stable mean ankle, knee, and hip kinetic values during double-leg jumping (Rodano & Squadrone 2002); and twenty strides for stable kinematic and spatiotemporal values whilst running on a treadmill (Riazati, Caplan, & Hayes 2019). Hence, the LESS calculation method using the mean of the 3 trials or sum of errors present in at least two jumps are recommended over single trial methods to represent typical movement patterns.

The main limitation of this study is that group-level and individual-level risk categorization were based on a threshold of 5 errors per Padua et al., (2015) This threshold derives from a population of young (13.9 ± 1.8 years) elite male and female soccer players and might not be appropriate for our population of predominantly young physically active adults (18.1 ± 4.3 years). Another limitation is that we set the mean of 3 jumps as a reference method given its frequent use (Beese et al., 2015; Beutler et al., 2009; DiStefano et al., 2018; DiStefano et al., 2009; Kuenze et al., 2015; Mohammadi et al., 2017; Padua et al., 2015; Padua et al., 2012; Pfile et al., 2016; Scarneo et al., 2017; Smith et al., 2012; Theiss et al., 2014; Welling et al., 2016; Wesley et al., 2015) even though this method is not necessarily a "gold standard" method. It is important to note that our study assessed the difference between LESS computational methods on scores and risk categorization of individual. Our study did not assess which scoring method has the greatest predictive ability, with only the mean of 3 jumps method used for this purpose to date (Padua et al., 2015; Smith et al., 2012). Moreover, the Bonferroni method used to adjust 95% confidence intervals and *p*-values during post-hoc comparisons is a conservative method and could inflate Type II error. However, the interpretation of our results would not be altered by changing the adjusting method given how far away our *p*-values were from the set significance level of $p \leq 0.05$.

<u>Conclusion</u>

This paper found that final LESS score calculation methods can influence estimated group mean LESS scores, group-level risk categorization, and individual-level risk categorization to various extents. In line with our expectations, the best jump method exhibited the greatest difference in group mean LESS score from the reference method. The significant difference of 0.92 errors in LESS score between methods is clinically meaningful based on reported psychometric properties across the scientific literature (Hanzlíková & Hébert-Losier 2019); and therefore, interpreting results from studies or clinical practices using the best jump computational method in relation to the reference method should be done with caution. Using the mean score from the 3 DVJ trials is the most common in the scientific literature and the only one with demonstrated predictive ability (Padua et al., 2015; Smith et al., 2012), and hence, likely the most justifiable. However, when there are time or financial restrictions, scoring the 3rd jump offers a suitable option when mean group score is of interest, whereas scoring the 1st jump is a viable option when the group-level risk categorization is of interest. When both are of interest, the former option offers the best compromise. Clinicians should bear in mind that human movement is variable and that scoring a single trial only may not represent the typical performance of an individual. Selecting the mean of 3 trials or sum of errors present in at least 2 trials methods reflects typical LESS performance and individual movement errors than single trial methods. The different LESS calculation methods provide different information, outcomes, and clinical interpretations that need consideration in research and practice.

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