Original research

Validity of clinical outcome measures to evaluate ankle range of motion during the weight-bearing lunge test

Emily A. Hall a,*, Carrie L. Docherty b

a Department of Orthopaedics and Sports Medicine, Morsani College of Medicine, University of South Florida, Tampa, FL, United States
b Department of Kinesiology, School of Public Health, Indiana University, Bloomington, IN, United States

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A B S T R A C T

Objectives: To determine the concurrent validity of standard clinical outcome measures compared to laboratory outcome measure while performing the weight-bearing lunge test (WBLT).

Design: Cross-sectional study.

Methods: Fifty participants performed the WBLT to determine dorsiflexion ROM using four different measurement techniques: dorsiflexion angle with digital inclinometer at 15 cm distal to the tibial tuberosity (°), dorsiflexion angle with inclinometer at tibial tuberosity (°), maximum lunge distance (cm), and dorsiflexion angle using a 2D motion capture system (°). Outcome measures were recorded concurrently during each trial. To establish concurrent validity, Pearson product–moment correlation coefficients (r) were conducted, comparing each dependent variable to the 2D motion capture analysis (identified as the reference standard). A higher correlation indicates strong concurrent validity.

Results: There was a high correlation between each measurement technique and the reference standard. Specifically the correlation between the inclinometer placement at 15 cm below the tibial tuberosity (44.9° ± 5.5°) and the motion capture angle (27.0° ± 6.0°) was r = 0.76 (p = 0.001), between the inclinometer placement at the tibial tuberosity angle (39.0° ± 4.6°) and the motion capture angle was r = 0.71 (p = 0.001), and between the distance from the wall clinical measure (10.3 ± 3.0 cm) to the motion capture angle was r = 0.74 (p = 0.001).

Conclusions: This study determined that the clinical measures used during the WBLT have a high correlation with the reference standard for assessing dorsiflexion range of motion. Therefore, obtaining maximum lunge distance and inclinometer angles are both valid assessments during the weight-bearing lunge test.

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1. Introduction

An increased number of healthcare practitioners are utilizing evidence-based medicine principles in their clinical practice. Evidence-based medicine integrates research, clinical expertise, and patient preference to guide clinical decision making. 1 Researchers are encouraged to investigate clinical measures or techniques that are commonly used or most accessible in the clinical setting. 2 Incorporating clinical measures into research will ensure these measures and techniques are transferred to the clinical setting. For many injuries to the lower extremity, assessing dorsiflexion range of motion is essential to identify risk factors 3 or alterations in gait or landing mechanics. 4

The weight-bearing lunge test (WBLT) is a clinical test that measures dorsiflexion range of motion of the ankle joint. The WBLT has been used to detect range of motion deficits in those with chronic ankle instability 5 and track progress in improving range of motion during rehabilitation protocols. 6 The WBLT has been established as a reliable measure, 7–9 however, no current research exists comparing the WBLT to a laboratory measure of joint kinematics. Based off a recent systematic review, 10 a variety of procedural differences have been utilized in published research when obtaining data on the WBLT. 8,11,12 Specifically, WBLT data can be quantified using either a digital inclinometer or maximum lunge distance from the wall. Previous research has determined a high correlation between the angle using a digital inclinometer and the distance from the wall, 7 but the placement of the digital inclinometer has also varied between studies (i.e. tibial tuberosity 9,11 or 15 cm distal to the tibial tuberosity 7 ).

* Corresponding author.
E-mail address: eannehall@health.usf.edu (E.A. Hall).

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Validity is defined as the degree to which an instrument truly measures the construct(s) it purports to measure.\textsuperscript{13} Concurrent validity is a subset of test validity that compares a test with an established measure. A higher correlation indicates that the test has strong concurrent validity with the ‘established’ measure in the literature. The ‘established’ measure for assessing range of motion in the laboratory setting is a video motion capture analysis.\textsuperscript{14} There have been no concurrent validity studies between the clinical measures and video motion capture analysis during the WBLT. Therefore, the purpose of this study is to determine if the clinical measures are valid assessments of range of motion compared to the laboratory measures during the weight-bearing lunge test.

2. Methods

Fifty participants between the ages of 18–35 were eligible to participate in this study (25 males, 25 females, 24.2 ± 3.5 years, 172.8 ± 10.3 cm, 76.4 ± 16.6 kg, 43 right foot dominant, and 7 left foot dominant). Prior to participation, all participants completed a Physical Activity Readiness Questionnaire (PAR-Q) and a health history questionnaire. The sample included participants with a heterogeneous age, physical activity level, and history of lower extremity injury. A heterogeneous sample was employed for this validity study to improve external validity regardless of the type of sample tested.\textsuperscript{15,16} Therefore, the exclusion criteria were limited to if they answered yes to any questions on the PAR-Q or if they were unable to perform the tests without pain or discomfort. Before participating in the study, all participants read and sign an informed consent form approved by the University’s Institutional Review Board for the Protection of Human Subjects, which also approved the study.

The WBLT was performed using four different measurement techniques: digital inclinometer placed at the tibial tuberosity, digital inclinometer placed 15 cm distal to the tibial tuberosity, a tape measure, and a two-dimensional video camera. Participants performed the WBLT on their dominant limb.\textsuperscript{17} The participants lunged forward trying to touch a vertical line on the wall with their knee while maintaining heel contact with the ground.\textsuperscript{2,18} Touching the vertical line perpendicular to the floor helped control subtalar joint movement and standardized between participants. The contralateral limb was positioned behind the testing limb in a comfortable position and hands were placed on the wall in front to maintain stability (Fig. 1). If they were able to maintain heel and knee contact, they moved their foot away from the wall in order to reach maximum dorsiflexion range of motion. Participants performed three practice trials followed by 3 test trials. Each dependent variable (angle at 15 cm (\textdegree), angle at tibial tuberosity (\textdegree), motion capture angle (\textdegree), and maximum lunge distance (cm)) were performed concurrently during each trial. Participants were instructed to dorsiflex as far as possible, but no encouragement was provided during the testing. The exact procedures for capturing each dependent variable is explained in the following paragraphs.

Using a digital inclinometer (Acumar, Lafayette Instruments, Lafayette, IN) at two different positions, maximal dorsiflexion was determined. Based on previous research, the inclinometer positions were 1) at the tibial tuberosity\textsuperscript{9,11} and 2) at 15 cm distal to the tibial tuberosity.\textsuperscript{7} Each position was marked with a pen and the center of the inclinometer was placed at that position. Prior to each participant, the inclinometer was calibrated to a 90\textdegree angle using a level. During each trial, the value was stored in the inclinometer and transferred to an excel worksheet to prevent investigator recall bias. Assessor was blinded to the values after all three trials were complete. The value from the inclinometer at their maximal dorsiflexion position was recorded and the mean of the three test trails was used for statistical analysis.

Maximum lunge distance was recorded using a standard tape measure secured to the floor. The measurement was obtained between the great toe and the wall, to the nearest 0.1 cm. The value was recorded after each trial and the mean of three test trials was used for statistical analysis.

A two-dimensional motion capture analysis (MAXTraq 2D, Innovation Systems Inc., Columbusville, MI) was employed as the reference standard. Reflective markers were placed at the tibial plateau, lateral malleolus, and base of the 5th metatarsal. For calibration purposes, data were captured for 5 s when the participant stood with their feet shoulder width apart. The difference between the standing trial and each maximum dorsiflexion range of motion during the WBLT trials were calculated and the mean of the three test trials was used for statistical analysis.

To establish concurrent validity, Pearson product–moment correlation coefficients (r) were conducted, comparing each dependent variable to the reference standard (2D motion capture analysis). Distance to angle ratio was also calculated from the line of best fit equation on the scatter plot. Finally, analyses between each angular clinical measure to the reference standard were explored using the Bland–Altman plots. All statistical analyses were performed using SPSS Version 22 (SPSS, Inc., Chicago, IL). Correlation coefficients were interpreted in the following manner based on previous literature: negligible (0.0 < r < 0.3), low (0.3 ≤ r < 0.50), moderate (0.5 ≤ r < 0.7), high (0.7 ≤ r < 0.9), or very high (0.9 ≤ r ≤ 1.0).\textsuperscript{19}

3. Results

Descriptive data with means, standard deviations, mean differences, and 95% limits of agreement were calculated for each outcome measure (Table 1). There was a high correlation between each measure and the reference standard. Specifically, the correlation between the angle when the inclinometer was placed at 15 cm below the tibial tuberosity and the motion capture angle was r = 0.76 (p = 0.001) (Fig. 2a). The correlation between the angle when the inclinometer was placed at the tibial tuberosity and the motion capture angle was r = 0.71 (p = 0.001) (Fig. 2b). The correlation when the distance from the wall measure was related to the motion capture angle was r = 0.74 (p = 0.001) (Fig. 2c). After analyzing the distance to angle ratio, we determined that for every 2 cm distance from the wall, there was an increase in 1\textdegree compared to the motion capture angle. The Bland–Altman plots are located in Fig. 3. Please cite this article in press as: Hall EA, Docherty CL. Validity of clinical outcome measures to evaluate ankle range of motion during the weight-bearing lunge test. J Sci Med Sport (2017), http://dx.doi.org/10.1016/j.jsams.2016.11.001
Table 1
Means, standard deviations (SD), mean differences, and 95% limits of agreement for each outcome measure.

<table>
<thead>
<tr>
<th>Outcome measure</th>
<th>Mean ± SD</th>
<th>Mean difference to reference standard</th>
<th>95% limits of agreement (upper, lower)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2D motion capture angle (°)</td>
<td>27.0 ± 6.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Angle @ 15 cm (°)</td>
<td>44.9 ± 5.5</td>
<td>17.9 ± 4.0</td>
<td>25.8, 10.1</td>
</tr>
<tr>
<td>Angle @ tibial tuberosity (°)</td>
<td>39.0 ± 4.6</td>
<td>12.0 ± 4.3</td>
<td>20.4, 3.6</td>
</tr>
<tr>
<td>Maximum lunge distance (cm)</td>
<td>10.3 ± 3.0</td>
<td>16.7 ± 4.3</td>
<td>25.2, 8.2</td>
</tr>
</tbody>
</table>

*a* Indicates a significant correlation between the outcome measure and the 2D motion capture angle.

Fig. 2. Scatter plots of the Pearson Product–Moment Correlation of A) 2D versus inclinometer angle at 15 cm distal to the tibial tuberosity, B) 2D versus inclinometer angle at tibial tuberosity, and C) 2D angle versus the distance from the wall.

4. Discussion

This was the first known study to evaluate the concurrent validity of clinician-oriented outcomes compared to their laboratory-oriented outcomes during the WBLT. Previously, high concurrent validity has been established between an electrogoniometer and motion capture analysis of hip, knee, and ankle during ballet movements, as well as high concurrent validity between a digital inclinometer and universal goniometer at the hip. This is the first study to assess the validity of ankle range of motion during the WBLT. These results indicate that the both inclinometer angles and the maximum lunge distance have a high correlation with the motion capture angle (ranging from 0.71 to 0.76). Therefore, any can be utilized as valid clinical measures when performing the WBLT. Since a digital inclinometer is not always available in the clinical setting, measuring maximum lunge distance from the wall may be another valid option. Using a tape measure is also a cheaper alternative to purchasing a digital inclinometer. Previous research found that for every 1 cm away from the wall, there was a 3° increase in ankle dorsiflexion. In our study, for every 1 cm away from the wall, there was a 2° increase in ankle dorsiflexion.

When comparing the inclinometer and reference standard, the discrepancy in values of the angular measures could be a result of
the calibration method used for each measure. This was confirmed using the Bland–Altman plots. We determined a systematic bias for each clinical measure compared to the reference standard. When the inclinometer was placed at 15 cm distal to the tibial tuberosity a bias of 17.9° resulted. When the inclinometer was placed on the tibial tuberosity a bias of 12.0° was identified. As described in the methods, the 2D motion capture angle was standardized to each participant’s standing lower limb angle. However, based on previously published procedures, the inclinometer measures were standardized to a 90° angle using a level.9,11 We hypothesize that this calibration difference was the primary factor in creating a systematic bias. Future research should consider calibrating the digital inclinometer to the participant’s quiet stance.

There were also differences between the angle measured at the tibial tuberosity and 15 cm below the tibial tuberosity. This could be due to the placement of the inclinometer on the tibial tuberosity slightly varied between participants depending how close the participant’s foot was to the wall. The investigator found it difficult to place the digital inclinometer without obstruction on the tibial tuberosity in participants with less ankle range of motion. This obstruction occurred when participants were about 6 cm from the wall and closer. While one study6 that placed the inclinometer on the tibial tuberosity using the knee-wall technique reported that there was no inclinometer obstruction. Another previous study11 which had a similar obstruction issue, performed a modified weight bearing lunge test but did not perform the knee-to-wall technique. They instructed participants to lunge forward with their contralateral limb in front. While this modified technique eliminates the obstruction issues, it has not been consistently used in previous literature and subsequently was not investigated in the current study.

One limitation to this study was the experience of the investigator performing the WBLT. Investigator was considered to be a novice rater with only 6 months of experience, although previous research found that difference in skill level and experience of the raters did not appear to influence the reliability of the WBLT.7 Another possible limitation was that we did not control for posterior talar displacements, foot length, or leg length because previous research did not identify significant relationships on the WBLT performance.8 Recall bias was also present in this study during recording of the distance from the wall. The inclinometer angles and 2D motion capture angles were stored in the device and processed after the participant completed the trials. Future research should further analyze the differences in values of the inclinometer and motion capture angles when it is standardized to the participant’s standing calibration. Another method to standardize between participants would be to include taking a percentage of the participants’ shank length instead of the constant of 15 cm.

5. Conclusion

Using valid clinical measures is an important aspect of evidence-based clinical practice. This study determined that the clinical measures used during the WBLT have a high correlation with the laboratory measure of assessing dorsiflexion range of motion. Therefore, obtaining maximum lunge distance and inclinometer angles are valid assessments during the weight-bearing lunge test.

Practical implications

• Incorporating clinical measures into research will ensure these measures and techniques are transferred to the clinical setting.
• Improving lunge distance and inclinometer angles are valid clinical measures during the weight-bearing lunge test.
• Obtaining valid clinical measures will provide better patient care.

Acknowledgment

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References