Reliability of the Active-Knee-Extension and Straight-Leg-Raise Tests in Subjects With Flexibility Deficits

Tiago Neto, Lia Jacobsohn, Ana I. Carita, and Raul Oliveira

Context: The active-knee-extension test (AKE) and the straight-leg-raise test (SLR) are widely used for flexibility assessment. A number of investigations have tested the reliability of these measures, especially the AKE. However, in most studies, the sample involved subjects with normal flexibility. In addition, few studies have determined the standard error of measurement (SEM) and minimal detectable difference (MDD), which can provide complementary and more clinically relevant information than the intraclass correlation coefficient (ICC) alone. Objectives: This study aimed to determine the AKE and SLR intrarater (test–retest) reliability in subjects with flexibility deficits, as well as the correlation between the 2 tests. Design: Reliability study, test–retest design. Setting: Academic laboratory. Subjects: 102 recreationally active participants (48 male, 54 female) with no injury to the lower limbs and with flexibility deficits in the hamstrings muscle group. Main Outcomes: Intrarater reliability was determined using the ICC, complemented by the SEM and MDD. Measures: All participants performed, in each lower limb, 2 trials of the AKE and the SLR. Results: The ICC values found for AKE and SLR tests were, respectively, .87–.94 and .93–.97. The values for SEM were low for both tests (2.6–2.9° for AKE, 2.2–2.6° for SLR), as well as the calculated MDD (7–8° for AKE; 6–7° for SLR). A moderate to strong, and significant, correlation between AKE and SLR was determined for the dominant limb (r = .71) and the nondominant limb (r = .67). Conclusions: These findings suggest that both AKE and SLR have excellent intrarater reliability. The SEMs and MDDs recorded are also very encouraging for the use of these tests in subjects with flexibility deficits.

Keywords: flexibility assessment, hamstrings, intraclass correlation coefficient, standard error of measurement, minimal detectable difference

Flexibility is an important physical parameter often related to athlete performance and is also frequently related to muscle injury. Consequently, poor flexibility, specifically affecting the hamstrings muscle group, has been linked not only to muscle strains but also to other conditions such as patellofemoral pain. Therefore, it is important to assess with precision and reliability an athlete’s flexibility, either to evaluate the progress of a training program or to measure the efficacy of strategies in a rehabilitation setting. The active-knee-extension test (AKE) and the straight-leg-raise test (SLR) are 2 of the most commonly used measures for flexibility assessment. The AKE consists of an active extension movement at the knee joint (with the hip flexed at 90°), in which the subject is instructed to stop when he or she feels strong resistance to the movement. On the other hand, the SLR is characterized by a passive hip-flexion movement, with the knee fully extended, performed by the examiner. Some authors defend the passive nature of the SLR, saying it represents an advantage over the AKE when evaluating hamstrings extensibility by eliminating quadriceps and hip-flexor activity. However, other studies have concluded that the subject’s positioning during AKE not only prevents pelvic rotation but also eliminates the confusion arising from possible neurological involvement that can occur during the SLR maneuver.

Reliability studies have been done using AKE, and others have used SLR as a gold standard for other measures. However, few investigations have compared the AKE and SLR in subjects with flexibility deficits. Literature shows that reduced hamstrings extensibility has a significant impact on pelvic motion. Given this, it is possible that individuals presenting with flexibility deficits have a higher variability in the flexibility measures, mainly due to pelvic compensations. In addition, in some cases reliability is only assessed by the intraclass correlation coefficient (ICC), where other measures such as the standard error of measurement (SEM) or the minimal detectable difference (MDD) might give additional...
and more valuable information, especially from a clinical point of view. The purposes of this study were to determine the test–retest reliability of the AKE and SLR and to examine how these 2 tests correlate with each other in the assessment of a population without injury but with flexibility deficits.

Methods

Participants

One hundred two subjects (48 men, 54 women) volunteered to participate in this study. Their mean ± SD age, height, and weight were 23.8 ± 3.5 years, 1.67 ± 0.1 m, 67.9 ± 13.3 kg, respectively. All subjects were injury free at the time of the study and did not have a history of knee or hip surgery. They were physically active, but without engaging in competition-level sports, and had flexibility deficits, defined by Bandy et al11 as achieving less than 60° of knee extension as measured in the AKE test position. Written informed consent was obtained from all participants according to the Helsinki Declaration.

Procedures

All procedures concerning data collection were executed in the same day. Before the flexibility assessment, information regarding height, weight, and lower-limb dominance (which was classified according to the subject’s favorite leg for kicking a ball) were collected.

Regarding the flexibility assessment, all goniometric measures were made by the same experienced physical therapist. During the AKE test, the subjects were blind to the goniometric reading, and during the SLR test, the examiner who performed the lower-limb movement was also blind to the goniometric reading. Both lower limbs were assessed in 2 separate trials of the AKE and SLR tests. For both tests, the subjects were familiarized with the experimental setup and procedures before data collection. They were placed in the test position, and all the instructions and commands were explained and practiced with them.

The AKE was performed using an experimental apparatus designed specifically for this investigation. It consisted of a rectangular wooden frame that was attached to an examination table. Participants were instructed to lay supine on the table, facing the wooden frame, as observed in Figure 1. The tested limb was flexed until the thigh touched the wooden frame, being at 90° with the table. The contralateral limb was fully extended and stabilized in neutral rotation by a second examiner. With the foot in neutral position and the knee flexed at 90°, a standard universal goniometer was placed over the lateral femoral condyle, with 1 arm aligned along the thigh in the direction to the greater trochanter and the other arm aligned over the leg in the direction of the lateral malleolus. From this position, and without any prior warm-up, subjects were instructed to extend the knee until they felt a strong resistance, holding this final position for 2 to 3 seconds to allow the goniometric reading. The result recorded corresponded to the amplitude, in degrees, of the knee-extension movement, starting from the initial test position (knee flexed at 90° which corresponded to the goniometric 0°). After the goniometric reading, the tested leg resumed the resting position for 1 minute, after which the same procedures were executed for the second trial.

For the SLR test, a normal examination table was used. Participants lay supine and were told to relax throughout the test. The tested limb was flexed by the examiner, with the knee fully extended and the foot in a relaxed position. The contralateral limb was secured by a second examiner, fully extended and in neutral rotation. The movement stopped when the tester felt a strong resistance or when pelvic rotation was observed. The goniometer was placed over the greater trochanter, with 1 arm aligned with the lateral femoral condyle and the other aligned parallel to the table, in the direction of the midaxillary line. As described for the AKE, in the SLR test the subject also resumed a resting position after the goniometric reading. The second trial was performed after a 1-minute rest period. Between the AKE and the SLR measurements subjects rested for 10 minutes.

Statistical Analysis

Descriptive statistics including means and standard deviations were used for all variables. The correlation between AKE and SLR values was assessed by Pearson coefficient ($r$). Paired $T$ tests were used to compare the difference between measures from the first to the second trial. Test–retest reliability assessment included ICC, SEM, and MDD. An ICC using a 1-way random effect (1,1) was used.12,13 SEM was determined using the equation

$$\text{SEM} = \sqrt{\text{mean}_{ws}}$$

where mean$_{ws}$ represents the within-subject mean square value obtained from the 1-way random-effects analysis of variance.13 The MDD was calculated using the equation13
MDD = 1.96 \times \sqrt{2} \times SEM

Statistical significance was set, for all tests, at $P < .05$.

**Results**

The mean values and standard deviations for both trials made for each lower limb for the AKE and SLR are presented in Table 1. Paired 7 tests did not show any difference between the 2 measurements for SLR and AKE, in either the dominant or the nondominant leg.

Information regarding the reliability measures is presented in Table 2. Pearson correlation coefficient between AKE and SLR for the dominant side was $r = .71$ ($r^2 = .51$), and for the nondominant side was $r = .67$ ($r^2 = .45$)

**Discussion**

This study’s main purpose was to assess test–retest reliability of the AKE and SLR tests in a sample of subjects with flexibility deficits. Results from ICC, SEM, and MDD suggest that these flexibility tests have a high degree of reliability between trials performed by the same tester. We obtained an average ICC of .91 for AKE and .96 for SLR, which is consistent with high reliability values. In addition, the SEM values collected (2.2° for SLR and 2.9° for AKE) lead us believe that there is a high precision in the individual scores, using either AKE or SLR. Regarding MDD, which might be of particular interest for clinical or training purposes, excellent values were also obtained (6° for SLR, 8° for AKE).

These results are consistent with previous publications regarding AKE and SLR test–retest reliability. Hamid et al. found an intrater ICC of .92 for AKE in the dominant leg and .88 for the nondominant leg. Another study reported a similar value for the intratester ICC (.86) regarding the AKE test. Aalto et al. also reached an excellent intrater ICC value (.95) for the SLR test. In all these studies subjects were considered to have normal flexibility, unlike our population.

In this investigation, we used other measures besides the ICC to give more information about the test–retest reliability of these flexibility tests. The SEM represents a good complement for the reliability study, given that it quantifies the precision of individual scores on a test and has the same unit of the variable being measured. Knowing the SEM, we can determine the MDD, which is defined as the difference needed between separate measures to be considered real. Hence, for clinical purposes the SEM, together with the MDD, provides more valuable information than the ICC alone. Our SEM values are lower than those referenced for the dominant (3.5°) and nondominant leg (3.8°) during the AKE test. The MDD values that we determined were also lower than those reported by Reurink et al. (18° for the uninjured leg). In the current study we assessed intratester reliability; Reurink et al. assessed intertester reliability, so comparisons should be limited. Regarding SLR as a measure of flexibility, we did not find any comparison for the SEM or MDD values collected. To our knowledge, this is the first study to report such a measure of absolute reliability for the SLR test. This information has particular relevance for rehabilitation and training settings. Clinicians and trainers can use these MDD values to determine if a specific flexibility training is succeeding.

We found a significant correlation between AKE and SLR results. These $r$ values are higher than those obtained in the literature ($r = .43$). Cameron and Bohan reported an $r$ value (.71) similar to this study, but they used an active version of the SLR. However, the common variance that we reached for the AKE and SLR tests was only 45% to 51%, which means that there are some differences that characterize these measures and that probably explain the variability in the flexibility results. Although both the AKE and the SLR tests assess primarily hamstrings extensibility, they do so by different forms. The fact that the AKE is an active test, where the subject dictates the movement endpoint, while SLR is a passive test, where the movement is stopped by the tester, might explain some of the variability between the tests. In addition, it was recently proven that asymmetries in a subject’s pelvic position during the AKE test are responsible for significant differences in the final popliteal-angle outcome. It is possible that during the SLR test the pelvic position’s influence is even greater. This fact might be even more significant when dealing with subjects with flexibility deficits. Hamstrings with low extensibility will cause a posterior pelvic rotation.

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**Table 1** Results (°) for Both Trials of Active Knee Extension (AKE) and Single-Leg Raise (SLR) in the Dominant (Dom) and Nondominant (Nondom) Legs, Mean ± SD

<table>
<thead>
<tr>
<th></th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>AKE Dom</td>
<td>45.3° ± 9.3°</td>
<td>45.2° ± 10.1°</td>
<td>.867</td>
</tr>
<tr>
<td>AKE Nondom</td>
<td>44.1° ± 8.8°</td>
<td>44.2° ± 9.0°</td>
<td>.729</td>
</tr>
<tr>
<td>SLR Dom</td>
<td>67.5° ± 10.9°</td>
<td>67.6° ± 10.8°</td>
<td>.781</td>
</tr>
<tr>
<td>SLR Nondom</td>
<td>66.0° ± 11.0°</td>
<td>65.7° ± 11.5°</td>
<td>.399</td>
</tr>
</tbody>
</table>

**Table 2** Reliability Measures for Active Knee Extension (AKE) and Single-Leg Raise (SLR) in the Dominant (Dom) and Nondominant (Nondom) Legs

<table>
<thead>
<tr>
<th></th>
<th>ICC (95% CI)</th>
<th>SEM (°)</th>
<th>MDD (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AKE Dom</td>
<td>.91 (.87–.93)</td>
<td>2.9</td>
<td>8</td>
</tr>
<tr>
<td>AKE Nondom</td>
<td>.91 (.88–.94)</td>
<td>2.6</td>
<td>7</td>
</tr>
<tr>
<td>SLR Dom</td>
<td>.96 (.94–.97)</td>
<td>2.2</td>
<td>6</td>
</tr>
<tr>
<td>SLR Nondom</td>
<td>.95 (.93–.97)</td>
<td>2.6</td>
<td>7</td>
</tr>
</tbody>
</table>

Note: ICC indicates intraclass correlation coefficient; CI, confidence interval; SEM, standard error of measurement; MDD, minimal detectable difference.
which can increase the variability between the AKE and SLR results.

From a clinical point of view, the high intrarater reliability values obtained in this study lead us believe that both tests can be used with minimal bias. The reason for choosing 1 particular test over the other must be made by the clinician in compliance with his or her clinical evaluation. To choose which test to use, considerations must be made regarding the passive versus active nature of the movement, the specific purpose of the assessment (posterior thigh vs the entire lower limb), and AKE-apparatus availability.

This study has some limitations. One was due to methodological constrains that did not allow for the main examiner (who performed the goniometric reading) to be blind regarding the study’s purpose. However, we believe that 2 circumstances helped reduce any eventual bias. First, the main examiner did not perform any segment movement during the AKE or the SLR. Second, both the second examiner and the subject were blind to the goniometric reading. In addition, future investigations should address the intertester reliability for these measures, to increase their value as important clinical/training tools for flexibility assessment.

This reliability study provides information that can help trainers, researchers, or clinicians choose the right tool for flexibility assessment and reevaluation purposes, particularly when dealing with individuals with flexibility deficits.

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References


