Passive Knee-Extension Test to Measure Hamstring Tightness: Influence of Gravity Correction

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**Context:** A passive knee-extension test has been shown to be a reliable method of assessing hamstring tightness, but this method does not take into account the potential effect of gravity on the tested leg. **Objective:** To compare an original passive knee-extension test with 2 adapted methods including gravity’s effect on the lower leg. **Design:** Repeated measures. **Setting:** Laboratory. **Participants:** 20 young track and field athletes (16.6 ± 1.6 y, 177.6 ± 9.2 cm, 75.9 ± 24.8 kg). **Intervention:** Each subject was tested in a randomized order with 3 different methods: In the original one (M1), passive knee angle was measured with a standard force of 68.7 N (7 kg) applied proximal to the lateral malleolus. The second (M2) and third (M3) methods took into account the relative lower-leg weight (measured respectively by handheld dynamometer and anthropometrical table) to individualize the force applied to assess passive knee angle. **Main Outcome Measures:** Passive knee angles measured with video-analysis software. **Results:** No difference in mean individualized applied force was found between M2 and M3, so the authors assessed passive knee angle only with M2. The mean knee angle was different between M1 and M2 (68.8 ± 12.4 vs 73.1 ± 10.6, \( P < .001 \)). Knee angles in M1 and M2 were correlated (\( r = .93, P < .001 \)). **Conclusions:** Differences in knee angle were found between the original passive knee-extension test and a method with gravity correction. M2 is an improved version of the original method (M1) since it minimizes the effect of gravity. Therefore, we recommend using it rather than M1.

**Keywords:** flexibility, thigh, hip

Controversial relationships between hamstring tightness and injury prevalence are reported in the literature. Nevertheless, hamstring flexibility remains one of the most common assessments performed in sports therapy. Several methods have been proposed to evaluate hamstring flexibility, including the sit-and-reach test, different modifications of the original sit-and-reach test, an active knee-extension test, and finally a passive knee-extension test. The latter test is designed to minimize the associated pelvic motion, to have an objective fixed end point, and to be convenient and quickly performed. The subject is supine on an examination table and the tested leg is positioned in 120° or in 90° of hip flexion (0° = hip in straight position). Then the knee is passively extended by applying a standardized force of 7 kg for women and 8 kg for men with a dynamometer located just proximal to the lateral malleolus. When stabilized, the knee angle is measured with a goniometer.

This method has been shown to be reliable. In fact, no difference between the test–retest measures (\( r = .98 \)) was found. However, one may note that the method does not take into account the potential effect of gravity on the tested leg. Indeed, the closer to vertical it is, the lower the relative weight of the lower leg. As it was already shown in isokinetic testing, where the relative contribution of gravity to recorded torque values becomes increasingly large as the active torque generation decreases, it is important to correct values of a passive knee-extension test biased by gravitational effects to obtain a more accurate assessment of hamstring tightness. Therefore, the purpose of the current study was to compare an adapted method including gravity’s effect on the lower leg–foot complex with the original passive knee-extension test.

**Methods**

**Participants**

The subjects were 20 young male track and field athletes (16.6 ± 1.6 y, 177.6 ± 9.2 cm, 75.9 ± 24.8 kg) training in a national training center twice a day under the supervision of a coach in addition to their school time. Before data collection, all subjects were required to read and sign an informed consent approved by the local institutional review board.

**Experimental Design**

Each subject was tested in a randomized order with the different passive knee-extension tests. Between tests, the subjects rested seated for 10 minutes.
Passive Knee-Extension Test

In method 1 (M1), subjects were placed in the reference position: supine, the lumbar spine kept flat on the table, with the contralateral leg extended and the ipsilateral hip and knee flexed to 90° (Figure 1A). The hip was maintained in a neutral rotation position. Hamstring muscle tightness was measured with standard protocols: A force of 68.7 N (7 kg) was applied proximal to the lateral malleolus by the examiner using a handheld dynamometer (compact force gauge, Mecmesin, Slinfold, UK) to determine the passive knee angle (Figure 1B), 0° being the knee angle in the reference position and 90° being the extended knee. The angle was measured with video-analysis software (Dartfish Software, TeamPro, Fribourg, Switzerland).

The passive knee angle is easy to measure in adolescents since it requires them only to remain passive and relaxed. All measurements were video recorded and analyzed by the same investigator, with a good intratester reliability: intraclass coefficient, ICC (1, 1) = .80.

Passive Knee-Extension Test
With Measured Lower-Leg Weight

In method 2 (M2), in the reference position (Figure 1A), the handheld dynamometer was applied on the lower leg (proximal to the lateral malleolus) to determine its weight at this point (W_P, N). After that, we assessed hamstring tightness in the same way as in M1 (with a 68.7-N force) to find the passive knee angle (α). To determine the applied force (F) to be added to the 68.7 N, we multiplied the cosine of alpha by the weight of the lower leg:

\[ F = (\cos \alpha)W_P \]

Finally, we evaluated the passive knee angle with the new applied force (68.7 + F). The video-analysis software was used to determine the angle for M2 (Figure 1C).

Passive Knee-Extension Test
With Lower-Leg Weight Determined
From Anthropometrical Table

In method (M3), the subjects were weighed and measured (Holtain Ltd, Crosswell, Crymych, UK). Then, the weight (W = 6.1% of body weight), length (L = 28.5% of body size), and center-of-mass location (from the knee: 60.6% of the length of the lower leg–foot complex) of the lower leg–foot complex were determined from the anthropometrical table. To determine the lower-leg weight at the dynamometer pressure point (W_P2; proximal to the lateral malleolus), we used the following formula:

\[ W_{P2} = \left[ W(0.606L)/L \right] \]

After that, hamstring tightness was assessed in the same way as in M1 with the 68.7 N of pushing to find the alpha (α) angle. To determine the applied force (F_2) to add to this 68.7 N we used the following formula:

\[ F_2 = (\cos \alpha)W_{P2} \]

Each subject completed M3, but after statistical analysis (1-way repeated-measure analysis of variance [ANOVA] and a Tukey post hoc test), we did not find any difference between the individualized applied forces of M2 and M3 (79.4 ± 7.6 N for both M2 and M3), so we chose to evaluate passive hamstring flexibility only with M2 (see Discussion).

Statistical Analysis

Results are presented as mean ± SD. Since the data were normally distributed, differences in force between the 3 methods were tested with an ANOVA and a Tukey post
hoc test to localize the differences between means. Differences in knee angle between M1 and M2 were tested with a paired $t$ test. Pearson product–moment correlations were used to identify significant relationships. Statistical significance was set at $P \leq .05$ (SigmaStat 11.0, Systat Software, Chicago, IL).

**Results**

Values of force and knee angle are reported in Table 1. The one-way repeated-measures ANOVA showed significant differences in the mean applied force between the 3 methods ($F = 36.86$, df = 2, $P < .001$). The Tukey post hoc test found significant differences between M2 and M1 ($P < .001$) and between M3 and M1 ($P < .001$), but, as mentioned in the Methods section, no difference was found between M2 and M3. Applied force for M2 was correlated to applied force for M3 ($r = .93$, $P < .001$). The mean knee angle was significantly different between M1 and M2 ($t = -3.98$, df = 19, $P < .001$). Knee angle for M1 was correlated to knee angle for M2 ($r = .93$, $P < .001$).

**Discussion**

The current study shows significant differences in passive knee angle between M2 and M1. The choice of the applied force in the original method was empirical. It was based on the feeling of the subjects and on an unpublished, preliminary study, where a linear relationship between the applied force (4–10 kg) and the knee angle was found.6 To include gravity correction, we chose to add the relative weight of the lower leg–foot complex to the 68.7 N of the original method. This addition can explain the difference in passive knee angle between M1 and M2, but one may argue that M2 is a more accurate method for assessing passive hamstring flexibility.

This study also shows that the mean knee angle in M2 was well correlated with the mean knee angle in M1. This result is not surprising, given the repeated nature of M2 in regard to M1.

However, as shown in Table 1, since the range of knee angle is smaller with M2 than with M1, we speculated that a modified M2 (with a force added to a lower force than 68.7 N) would lead to a larger range of knee angle. This could potentially be a more discriminative method for assessing hamstring flexibility.

We did not assess passive hamstring flexibility with M3 for the following reason: The mean applied forces were not statistically different between M2 and M3 and were well correlated ($r = .93$, $P < .001$). In addition, we preferred M2 to M3 for its simplicity. In fact, M2 required less calculation and was easier and quicker, which is an important aspect for physiotherapists and researchers. It is not surprising to find the same force values for M2 and M3. In fact, in the reference position (Figure 1A), the passive structures of the knee (ligaments, articular capsule) and the thigh (tendons of hamstring and/or quadriceps muscles) are for the most part not in a stretch position. They influence to a negligible extent the relative weight of the lower leg–foot complex and therefore do not modify the weight obtained with M2.

Gravity correction is also an important factor when assessing populations with large differences in body dimensions, for example, in adolescents with various maturation status and body size (eg, in this study, a distance runner was 162.2 cm tall and weighed 41.3 kg, while a thrower was 183.3 cm tall and weighed 128.1 kg). One may assume that taking into account the weight of the lower leg relative to the angle would lead to a more precise and adapted measure of hamstring flexibility.

In practice, assessing passive knee extension with M2 is more complicated than with M1 because it involves assessing twice the same measure and calculating the cosine of alpha multiplied by the lower-leg weight. But M2 is an improved version of the original method (M1) since it minimizes the effect of gravity. Therefore, we recommend using it rather than M1.

**Table 1 Forces in M1, M2, and M3 and Knee Angles in M1 and M2**

<table>
<thead>
<tr>
<th></th>
<th>M1</th>
<th>M2</th>
<th>M3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Applied force, N</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mean ± SD</td>
<td>$68.7 \pm 0.0$</td>
<td>$79.4 \pm 7.6^*$</td>
<td>$79.4 \pm 7.6^*$</td>
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<tr>
<td>minimum</td>
<td>68.7</td>
<td>69.5</td>
<td>69.7</td>
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<tr>
<td>maximum</td>
<td>68.7</td>
<td>94.7</td>
<td>92.0</td>
</tr>
<tr>
<td>range</td>
<td>0.0</td>
<td>25.3</td>
<td>22.3</td>
</tr>
<tr>
<td><strong>Knee angle, °</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mean ± SD</td>
<td>$68.8 \pm 12.4$</td>
<td>$73.1 \pm 10.6^*$</td>
<td>NT</td>
</tr>
<tr>
<td>minimum</td>
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<tr>
<td>range</td>
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<td>36.2</td>
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</tr>
</tbody>
</table>

Abbreviations: M1, method 1; M2, method 2; M3, method 3; NT, nontested.

*Significant differences with M1 ($P < .001$).
Acknowledgments

This project was reviewed and approved by the institutional research and ethics committee of Aspetar, Qatar Orthopedic and Sports Medicine Hospital.

References