Pelvic Inclination Angle during the Straight Leg Raise Test and Knee Extension Test

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Abstract

Background: Shortening of the hamstrings has been evaluated using methods such as the straight leg raise (SLR) test and knee extension test. The angle of pelvic inclination during the SLR and knee extension test has been reported; however, there are no studies that have compared differences in the angles of pelvic inclination measured by both tests in the same subject.

Objectives: The purpose of this study was to clarify the differences in the angle of pelvic inclination between the SLR and knee extension tests.

Design: Cross-sectional study.

Methods: The subjects included 20 healthy students (male, n=11; female, n=9). The SLR and knee extension tests were performed on the subject’s right lower leg. The angle of pelvic inclination at the starting position and the angle of pelvic inclination and the SLR angle and knee extension angle at the end of the SLR and knee extension tests were measured. This measurement was performed under two conditions. The angle of pelvic inclination was set as the degree of change in the pelvic angle from the position at the start of the test to that at the end of the final test in both tests.

Results: The degree of change in the pelvic angle in the knee extension test was significantly smaller than that in the SLR test, under both fixed and non-fixed conditions.

Conclusion: The findings of the present study suggest that the knee extension test is superior for the evaluation of hamstring shortening because the compensatory movement (based on pelvic retroversion) during the test is smaller than that observed with the SLR test.

Keywords: Hamstrings; Straight Leg Raise; Knee Extension; Pelvic; Retroversion

Introduction

The hamstrings are a biarticular muscle with an origin at the ischial tuberosity and insertions in the fibula head or the medial condyles of the medial tibia. Shortening of the hamstrings has been evaluated by methods such as straight leg raise (SLR) test, knee extension test, sit-and-reach test and finger floor distance [1-5]. Among these tests, there is a high possibility that other factors, such as the inclination angle of the pelvis and the curvature of the spine, are also reflected in the results, especially the sit-and-reach test and the finger floor distance. Thus, it is possible that the shortening of hamstrings could not be evaluated using the values measured by these tests.

The SLR test indirectly evaluates shortening of the hamstrings based on the hip flexion angle at knee extension [1,2]. In the SLR test, it has been reported that pelvic retroversion occurs during the test [5] and the measurement result may reflect not only shortening of the hamstrings but also the influence of pelvic mobility. Compensatory movement based on pelvic retroversion during the test may therefore mask hamstrings shortening. In the clinical setting, individual differences in pelvic retroversion have been observed at the same SLR angle. If the pelvic angle is different at the time of the SLR test, the degree of extension of the hamstrings muscle may differ according to the difference in the angle of pelvic retroversion, even at the same SLR angle. Therefore, whether or not the SLR angle can accurately reflect hamstrings shortening remains questionable. Furthermore, when the hip joint is flexed, the presence of the pelvifemoral rhythm, which occurs in coordination with pelvic retroversion, has been reported. The extensibility of the hamstrings and presence of the pelvifemoral rhythm may be considered factors causing pelvic retroversion during the SLR test including hip flexion movement. In previous studies...
on the pelvifemoral rhythm [6-9], the ratio of the hip flexion angle to the pelvic retroversion was found to differ and the findings therefore remain inconclusive. The degree to which hamstring extensibility and pelvifemoral rhythm contribute to pelvic retroversion is unclear, so the accuracy of evaluating the shortening of hamstrings using the SLR test is debatable, despite the fact that this test is generally adopted in clinical practice.

Therefore, when evaluating shortening of the hamstrings, it is desirable to use a method that can be performed with no hip joint movement. The knee extension test is a method of indirectly evaluating shortening of the hamstrings by performing knee joint extension at a fixed hip flexion position [10-15]; therefore, this method is considered to be rarely affected by the pelvifemoral rhythm and the pelvic tilting motion during the test is reportedly small [10].

Measurement of the pelvic inclination angle during the SLR test and knee extension test has been performed by video shooting of markers affixed on the skin and then evaluated on the monitor screen [6,10]. However, Hara et al. reported that the deviation between the position of the bone index and the position of the marker increases with the hip joint flexion angle during the measurement compared to the initial position of the marker on the skin [16]. Therefore, measurement errors can occur when markers are directly affixed to the skin. In the present study, we determined the pelvic angle of inclination by attaching an inclination angle meter to the sacral portion of a pair of short leggings.

In previous studies, the inclination angle of the pelvis during the SLR test and the knee extension test has been reported [6,10], but there have been no reports comparing the pelvic inclination angle differences between both tests for the same subject. In addition, in previous studies [6,10], these reports used markers affixed to the skin to measure the pelvic inclination angle, resulting in a high possibility of errors being included in the measured values.

Considering the origin and insertions of the hamstrings, if the evaluation of hamstrings shortening can be carried out without pelvic retroversion, then the measurement value of the test would be highly relevant as an index of hamstrings shortening. The purpose of this study is to clarify the differences in the pelvic tilt angle between the SLR test and the knee extension test in health subjects using the inclinometer to ensure accurate measurements. We hypothesized that the pelvic tilt range of motion would be smaller during the knee extension test than the SLR test.

**Materials and Methods**

The subjects were 20 healthy students (11 males, 9 females). The height, weight and age of the subjects were 166.6 ± 10.1 cm, 61.0 ± 9.9 kg and 21.8 ± 0.9 years, respectively. Participants were free from neurological and orthopedic impairments. Based on the institutional ethics committee of Kanazawa University, explanations were given about the purpose of the research, measurement method and safety and a consent form was obtained from all subjects.

**Instrumentation**

A digital inclinometer (Digital Level BOX BM-801; Ito, Hyogo, Japan) was used to measure the angles of the pelvis, thighs and lower legs. This digital inclinometer has a minimum measurement value of 0.0 degrees, a maximum measurement value of 180.0 degrees and an accuracy of ± 0.2 degrees and measures in 0.1 degree increments. A laser level instrument (EXA-YR 21; STS, Nagoya, Japan) was used to define the starting position.

**Procedure**

All of the measurements described below were executed in the supine position on the measuring table with the subjects wearing short leggings and the upper limbs crossed in front of the chest. The right lower extremity was tested in all participants. In order to measure the angle of the pelvis, a digital inclinometer was fixed to the median sacral ridge above the skin at the posterior superior iliac spine level. All measurements were made on a measuring table specially prepared for the experiment. A 11×7-cm hole in the measuring table allowed the attachment of a digital inclinometer to the subjects’ pelvis while they were lying in a supine position (Figure 1). The digital inclinometer was attached to the anterior surface of the right thigh during the SLR test and to the anterior surface of the right tibia during the knee extension test.

**SLR test (Figure 2)**

The subjects lay on the table in the supine position. With the
knee fully extended, the tested extremity was passively raised to a point where the examiner felt firm resistance. The SLR angle was defined as the angle between the longitudinal axis of the femur and the trunk axis. The pelvic inclination angle at the starting position and the pelvic inclination angle and SLR angle at the end of the SLR test were measured. The above measurements were performed under two conditions, depending on whether or not the pelvis and the contralateral lower limb were fixed. Velcro straps® were used to fix the pelvis and contralateral limbs and the anterior iliac spine and the central part of the thigh were fixed to the measuring table. Measurements were registered five times per condition.

**Knee extension test (Figure 3)**

The subjects lay on the table in the supine position and the hip and knee joint of the examined side were determined by a laser level at 90° of flexion for both joints. While keeping the hip at 90° of flexion, the tested side knee was passively extended until the examiner felt firm resistance or the subject confirmed that the maximum knee extension had been reached. The knee extension angle was defined as the angle between the longitudinal axis of the lower leg and the line perpendicular to the longitudinal axis of the femur. The pelvic inclination angle at the starting position and the pelvic inclination angle and knee extension angle at the end of the knee extension test were measured. This measurement was performed under two conditions, depending on whether or not the pelvis and the contralateral limbs were fixed. Velcro straps were used to fix the pelvis and contralateral limbs and the anterior iliac spine and the central part of the thigh were fixed to the measuring table. Measurements were performed five times per condition.

In order to eliminate the order effect, the trial order of the SLR test and the knee extension test and the order of the conditions (fixed, not fixed) in each test were random. In addition, the SLR test and the knee extension test were carried out on different days. Boyce et al. reported that the sustained extension of the hamstrings for 15 seconds would expand the range of motion [17]. Thus, taking into consideration the fact that the measurement itself extends the hamstrings and influences the range of motion, both the SLR test and the knee extension test were held in the final position for less than 5 seconds. The time between 5 times of enforcement was 30 seconds.

All of the measurements were performed by two individuals (tester A, tester B). Tester A operated on the lower limbs of the subject, tester B read and recorded the values of the digital inclinometer.

The inclination angle of the pelvis was set as the angle change amount (pelvic angle change amount) from the test start position to the end of the final test in both tests (Figure 4). The average value of five measurements was taken as the representative value of the individual. A large change in the pelvic angle indicates a large degree of pelvic retroversion.

**Statistical Analyses**

For the quantity of change in the pelvic angle, a two-way analysis of variance (ANOVA) of two factors (with or without fixation of pelvis and contralateral lower extremity) was carried out. A simple main effect test was conducted if the ANOVA showed significant interaction. Statistical significance was set at P < 0.05. All data were analyzed using the SPSS software program, ver. 23 (IBM, SPSS Tokyo, Japan).

**Results**

The maximum SLR angle, the maximum knee extension angle and the pelvic angle change amount are shown in (Table 1). On the ANOVA, interaction was observed between the test method and the fixation of the pelvis and contralateral lower limbs. The simple main effect test showed that the pelvic angle change amount was significantly smaller for the knee extension test than for the SLR test, both under the non-fixed condition and the fixed condition. In the SLR test, the pelvic angle change amount was significantly smaller in the fixed condition than in the non-fixed condition. In contrast, in the

<table>
<thead>
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<th>Maximum Angle (°)</th>
<th>Change in Pelvic Angle (°)</th>
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<tr>
<td></td>
<td>Fixed</td>
<td>Non-fixed</td>
</tr>
<tr>
<td>SLR</td>
<td>75.2±15.2</td>
<td>80.9±15.8</td>
</tr>
<tr>
<td>Knee extension</td>
<td>70.0±15.9</td>
<td>70.2±17.4</td>
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SLR, straight leg raise.

**Figure 4:** Pelvic angle change amount.

The inclination angle of the pelvis was set as the angle change amount from the test start position to the end of the final test (= angle B – angle A).

**Figure 3:** Knee extension test.
knee extension test, there were no significant differences in the pelvic angle change between fixed and non-fixed conditions.

Discussion

This study investigated the differences in the test method between the SLR test and knee extension test and the effects of body fixation on the pelvic angle change amount.

We first assessed the differences in the test procedure. The pelvic angle change amount was significantly smaller in the knee extension test than in the SLR test. In the SLR test, the flexion movement of the hip joint occurs from the test start position to the end of the test and pelvic retroversion was greatly present during the movement. In contrast, in the knee extension test, the flexion angle of the hip joint at the test start position was kept at 90° until the end of the test and no additional flexion motion of the hip joint occurred during the test. Therefore, the influence of pelvifemoral rhythm [7-9] and the pelvic retroversion were smaller with the knee extension test than with the SLR test.

With respect to the origin and insertions of the hamstrings, performing a test without pelvic retroversion when evaluating hamstring shortening will provide more accurate results. The findings of the present study therefore suggest that the knee extension test is preferable for evaluating hamstring shortening because the compensatory movement based on pelvic retroversion during the test is smaller than with the SLR test.

The influence of the upper fixation of the pelvis and contralateral lower limb on the pelvic tilt angle was also analyzed. In the SLR test, the pelvic angle change amount was significantly smaller under fixed conditions than non-fixed conditions. However, in the knee extension test, there were no significant differences in the pelvic angle change amount based on the presence or absence of fixation. In our study, the anterior superior iliac spine and the central part of the thigh were fixed to the measuring table using Velcro® straps. If force is applied from the upper side to the anterior superior iliac spine in the supine position, the pelvis can be stimulated to incline backwardly. Therefore, whether or not this forced-fixing method reduced the back inclination of the pelvis remains questionable.

Kane et al. [15] reported that the flexion angle of the hip joint on the contralateral side affected the posterior inclination motion of the pelvis when the hip flexed. Therefore, the pelvic retroversion under fixed conditions during the SLR test is likely due to the contralateral lower limb fixation keeping the contralateral hip extension angle at 0°. Furthermore, as the hip joint at the examination side is flexed with the SLR test, the pelvis tilts backward. If the contralateral lower limb is fixed to the table, the opposite hip joint becomes a relative extension position and the iliofemoral is stretched. We therefore considered that the pelvis was towed in the anteverision direction due to the tension of the iliofemoral, thereby inhibiting pelvic retroversion movement. However, in the knee extension test, there were no significant differences in the pelvic angle change amount between the presence and absence of fixation. Therefore, the knee extension test may prevent pelvic retroversion to some extent, independently of fixing the contralateral thigh, suggesting that the knee extension test can be performed more easily than the SLR test. Since faster and easier-to-perform methods are preferable when conducting a clinical examination, the knee extension test is recommended in the evaluation of hamstring shortening based on the present findings.

However, one limitation of the knee extension test is the fact that this test cannot evaluate the hamstring extensibility in subjects who are able to fully extend the tested knee at the established position. In addition, the subjects in the present study were healthy and young. Further studies in elderly subjects and subjects with lower back pain using the SLR and knee extension test under different conditions of body fixation are therefore needed.

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