Assessment of Hamstring Muscle Length in School-aged Children Using the Sit-and-Reach Test and the Inclinometer Measure of Hip Joint Angle

Background and Purpose. The sit-and-reach test (SRT) is commonly used to assess flexibility of the spine and length of the hamstring muscles. The purposes of this study were (1) to describe hamstring muscle length as reflected by use of the SRT and the hip joint angle (HJA) in children, (2) to examine the correlation between SRT and HJA measurements, and (3) to examine gender differences for both measures. Subjects. The participants were 410 school-aged children (211 girls, 199 boys). Methods. Each child performed the SRT. In the final position, the SRT score was obtained and the HJA was measured using an inclinometer placed over the sacrum. Results. A mean SRT value of 24 cm and a mean HJA value of 81 degrees were obtained for all subjects. There was a strong correlation between the SRT and HJA measurements ($r = .76$). There was a difference between boys and girls for both measures. Conclusion and Discussion. The results suggest differences in expectations for hamstring muscle length in boys and girls. Although scores for the SRT and HJA were correlated, we prefer to assess hamstring muscle length using HJA scores because these scores are not influenced by anthropometric factors or spinal mobility. The results of this study suggest that HJA measurements guide treatment more effectively than do SRT measurements. [Cornbleet SL, Woolsey NB. Assessment of hamstring muscle length in school-aged children using the sit-and-reach test and the inclinometer measure of hip joint angle. Phys Ther. 1996;76:850–855.]

Key Words: Fitness tests and measurements, Flexibility, Hamstring muscle length, Sit-and-reach test.
Physical fitness testing is a routine component of physical education classes in elementary and secondary schools throughout the United States. One area routinely addressed in most fitness tests is flexibility. The sit-and-reach test (SRT) or a modified version of the SRT is typically used to evaluate flexibility of the low back and hamstring muscles. A score is given based on the most distant point reached by both hands on a standardized box as the child being tested leans forward in a long-sitting position (Fig. 1). Passing scores are given when children can reach at least 2 cm beyond their toes. According to the American Alliance for Health, Physical Education, Recreation, and Dance (AAHPERD), this flexibility test is important because decreased flexibility, particularly in the hamstring muscles and the back, is thought to contribute to the development of low back pain, but data confirming this supposition have not been provided.

In the literature, the terms "flexibility" and "muscle length" are often used synonymously when referring to the ability of the hamstring muscles to be lengthened to their end range. For the purposes of this article, the term "muscle length" will be used to refer to the end range of the hamstring muscles.

The SRT has been the subject of many studies. A critique written by Kendall and studies performed by Jackson and colleagues suggest that the SRT score does not distinguish between the contributions of the low back and the hamstring muscles during this reaching activity. Jackson and colleagues investigated the relationships between the SRT and measures of hamstring muscle length (passive straight leg raise) and back flexibility. They reported that the SRT has moderate criterion-related validity when used to reflect hamstring muscle length but does not appear to provide a valid assessment of back motion. Several authors contend that anthropometric factors, such as disproportionate length of the limbs relative to the trunk, may influence the results of the SRT. Children with long legs and a short trunk, for example, may fail the test even though they have acceptable hamstring muscle length. Hopkins estimated that scapular abduction during the SRT may account for 3 to 5 cm of variation in the final score. A passing score on the SRT, therefore, may be the result of a variety of factors. These factors include various combinations of back motion and hamstring muscle length such as normal or increased motion in the back and increased hamstring muscle length (Fig. 1), decreased or normal back motion combined with increased hamstring muscle length (Fig. 2), or increased back motion combined with decreased hamstring muscle length (Fig. 3); anthropometric factors such as long arms or short legs relative to the trunk; and scapular abduction, which increases the reaching distance of the arms.

We contend that a standard SRT test position can be used and, if the final hip joint angle (HJA) is measured rather than the final position of the hands on the SRT box, this provides a better reflection of hamstring muscle length. Measuring the HJA rather than the distance...
must monitor the pelvic position throughout the test. For example, hip flexor shortness may pull the pelvis in the direction of anterior tilt. Use of this faulty starting position could result in an inaccurate assessment of short hamstring muscle length. The use of the long-sitting position allows both hips to move in the same direction and eliminates the need to stabilize the pelvis or consider the influence of hip flexor shortness.8

Another aspect of the SRT that needs to be considered is the criteria for passing the test. Currently, boys and girls are required to meet the same standard.1 Our clinical experience, however, suggests that boys and girls may normally have differences in hamstring muscle length.

The purposes of our study were (1) to characterize hamstring muscle length by use of the HJA and SRT scores in a sample of school-aged children and (2) to test three hypotheses related to these measures. These hypotheses were:

1. There would be a correlation between SRT scores and HJA scores.
2. There would be no difference between SRT scores for boys and girls.
3. There would be no difference between HJA scores for boys and girls.

Method

Subjects

A total of 410 children (211 girls and 199 boys) without known impairment of the musculoskeletal system affecting the spine or the lower extremities participated in the study. The subjects were students in kindergarten through sixth grade from public and private elementary schools in St Louis County, Illinois. The subjects’ ages ranged from 5 to 12 years, with a mean age of 7 years 10 months. Informed consent was obtained from the parents of all subjects.
**Figure 4.**
Superior view of the ruler on the sit-and-reach box.

**Instrumentation**
A standard sit-and-reach box* was used to position the subjects for the test, and the sliding ruler that is centered on the top of the box was used to obtain the SRT scores. The markings on the ruler were positioned so that the 23-cm mark represented the point at which the subjects' fingertips were in line with their toes (Fig. 4). In this way, the SRT score was always a positive number, even for the children who were unable to reach their toes. The minimal acceptable score to pass, as determined by AAHPERD,* is 25 cm, or 2 cm beyond the toes, for all ages and both genders and without consideration of anthropometric variables.

An inclinometer† (a circular, fluid-filled goniometer) was used to measure the HJA. The inclinometer was set so that 0 degrees represented the horizontal, or 0 degrees of hip joint flexion. The inclinometer was placed vertically on the sacrum so that the center of the inclinometer was aligned at the level of the posterior superior iliac spines.

Interrater reliability, using an inclinometer to measure the HJA, was examined for the first 20 subjects between tester 1 and tester 2. An intraclass correlation coefficient (2,1) of .98 indicated to us an acceptable level of interrater reliability for the HJA scores.

A passing HJA score was determined by the examiners to be 80 degrees or more of hip joint flexion. This value corresponds to what Kendall* considers normal if hamstring muscle length is normal, as determined by the final position of the hip joint during straight leg raising or the angle between the sacrum and the table during forward bending in the long-sitting position. Other investigators* also have used this value as a guideline for normal hamstring muscle length.

**Procedure**
Each child was seated on the floor with knees fully extended and ankles in neutral dorsiflexion against the box (Fig. 1). The child was instructed to place one hand on top of the other and slowly reach forward as far as possible while keeping the knees extended. The hands were kept aligned evenly as the subject reached forward along the surface of the box. Each child practiced the movement twice, and, on the third repetition, the SRT score (in centimeters) was recorded as the final position of the fingertips on the ruler. During the same trial, the inclinometer was placed over the sacrum and the HJA was measured and recorded.

**Data Analysis**
The mean for all subjects and the means for boys and girls were calculated for the HJA and the SRT. A t test for independent samples was used to examine differences between boys and girls for the HJA and the SRT. The Pearson product-moment correlation coefficient was used to examine the relationship between the SRT and the HJA. Raw scores were examined to determine the number of cases in which the scores on the two tests appeared to be contradictory. For example, some children were able to reach at least 25 cm on the SRT box but had decreased hamstring muscle length as defined by the HJA (Fig. 3), whereas other children could not reach the 25-cm mark but had normal hamstring muscle length (Fig. 5).

**Results**
The Table presents the means and standard deviations for the SRT and HJA. There was a difference between the scores for boys and girls on the HJA test ($t=7.81$, $df=408$, $P<.001$) and on the SRT ($t=5.50$, $df=408$, $P<.001$).

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*American Alliance for Health, Physical Education, Recreation, and Dance, 1900 Association Dr, Reston, VA 22091.
*Biorkinetics Inc, 1710 Westminster Way, Annapolis, MD 21401.
The correlation between the SRT and HJA scores was significant (r=.76, df=408, P<.001). The correlation between the SRT and HJA scores was significant (r=.76, df=408, P<.001). Although over half (58%) of the variability in the SRT scores was accounted for by the variability in the HJA scores, it is important to examine those 73 cases (18%) in which a child passed one test but not the other. For example, 25 children (6%) passed the SRT (≥25 cm) but failed the HJA test (<80°), indicating decreased hamstring muscle length. Although back motion was not measured using a modified Schober’s technique or the two-inclinometer technique, visual appraisal suggested that in most of these cases, the spine was relatively more flexible than the hips and contributed most to the total performance of forward bending (Fig. 3). Conversely, 48 children (12%) failed the SRT (<25 cm) but had passing HJA scores (≥80°), indicating normal to increased hamstring muscle length. In these cases, it appeared that either anthropometric factors (long legs, short arms or trunk) (Fig. 5) or limited flexibility in the spine prevented the children from reaching their toes during the SRT.

### Discussion

The overall mean for our HJA measurements (HJA=81°) correlates to the value previously suggested by Kendall as indicating normal hamstring muscle length (80°) in adults or children. In addition, our results indicate that hamstring muscle length is less in boys than in girls. This finding is supported by studies that suggest that in the 5- to 10-year-old age group, girls are more flexible than boys. Shephard and colleagues also found that in adults aged 45 to 75 years, scores on the SRT were greater for women than for men. These results suggest that we should modify our expectations for hamstring muscle length based on gender.

The correlation between the HJA and SRT scores suggests that both tests reflect hamstring muscle length. The SRT and modified versions of the SRT, however, continue to focus on the distance of the fingertips to the toes as the final measure. Because this measure is influenced by a variety of factors, as previously discussed, the results may be misleading when developing strategies for interventions.

In the majority of cases, the typical action taken in response to the SRT score is to have the child practice forward bending in the long-sitting position as an exercise to improve the score. Our concern about practicing the test as an exercise is greatest for children who have normal hamstring muscle length or for children who can reach their toes but have decreased hamstring muscle length. There is no evidence to support the need to increase hamstring muscle length beyond normal or that improving the SRT score is associated with a change in hamstring muscle length. As noted by Kendall and McCreary, having children who can reach their toes but who have short hamstring muscles practice the long-sitting stretch might further increase their back motion, and this could produce little change in their hamstring muscle length.

We believe that the use of the inclinometer to measure the HJA as an indicator of hamstring muscle length during the SRT is simple, yields reliable measurements, and is not influenced by anthropometric factors. We realize that this method does not include a measure of back motion. We contend, however, that the SRT is not a valid measure of back motion, and if back motion is considered important to measure, that other methods such as the use of the inclinometer have been described and should be used.

Our future studies will include (1) use of the inclinometer to measure both the HJA and lumbar spine motion in school-aged children and (2) investigation of a change in hamstring muscle length or back motion as a result of practicing forward bending in the long-sitting position.

### Conclusion

The measurement of flexibility is an important component of fitness testing. The SRT is useful for examining hamstring muscle length, but more attention needs to be given to the final position of the hip joint rather than the final position of the fingertips. Measuring the HJA with an inclinometer while using the SRT position, in our opinion, provides a reliable and simple measure that reflects hamstring muscle length. Examiners should also recognize that there are differences in hamstring muscle length between boys and girls.

### Acknowledgments

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**Table. Sit-and-Reach Test (SRT) and Hip Joint Angle (HJA) Values**

<table>
<thead>
<tr>
<th>Test</th>
<th>All Subjects (N=410)</th>
<th>Boys (n=199)</th>
<th>Girls (n=211)</th>
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<tbody>
<tr>
<td></td>
<td>X</td>
<td>SD</td>
<td>Range</td>
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<tr>
<td>SRT (cm)</td>
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<td>8</td>
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<tr>
<td>HJA (°)</td>
<td>81</td>
<td>11</td>
<td>54-111</td>
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</table>
References


